Washington State

Cooperative Monitoring, Evaluation, and Research Committee

(CMER)

Final Report

TYPE N STREAM DEMARCATION STUDY PHASE I: PILOT RESULTS

Prepared by

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For the

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EXECUTIVE SUMMARY

Non-fish bearing (Type N) streams are divided into seasonal (Type Ns) and perennial (Type Np) portions. Because forest practice regulations differ substantially between Np and Ns segments, an accurate estimate of the Np/Ns break is desirable.

The Type N Demarcation Study is intended to gather data to "refine the demarcation of perennial and seasonal Type N streams," a task identified in Schedule L-1 of the Forest & Fish Report (FFR). The pilot phase (phase 1) of this study was designed to:

- Test the adequacy and replicability of the pilot field protocol for identifying the Np/Ns break
- Estimate the size and variability of basin areas and other parameters
- Evaluate the potential for using basin and channel attributes to determine the Np/Ns break in the field

This information was collected for use in the larger statewide study envisioned to follow.

Ten cooperators (seven tribal, one state agency, and two timber industry) collected field data at a total of 224 Type N streams. Fifteen study areas were chosen by cooperators and included nine located on the Westside (one partially within the Coastal spruce zone) and six on the Eastside of the Cascade Crest. Within each study area, sites were selected either randomly or to revisit sites from past surveys. Data were collected during summer low flow conditions in 2001. At each study stream, field surveys documented the flow categories in each segment of 30 meters (~100 feet) or shorter. At each segment break channel width, depth, gradient, substrate, and associated features were recorded. The field data were subsequently analyzed to determine the location of three hydrologic transition points:

- Ch – the channel head
- Pd – the highest observed perennial water (may be continuous or discontinuous, flowing or standing). Pd is the regulatory Np/Ns break.
- Pc – the upper end of continuous perennial flow.

For consistency the basin area upstream from each Pd, Pc and Ch was delineated and determined on USGS topographic maps by a single technician within the ArcView GIS framework.

The statistical analysis summarized the field data, determined basin areas and variance, and alternative indicators of the Np/Ns break. All data distributions follow a lognormal distribution and appropriate transformations were used for statistical testing.

The key results of the pilot study are:

1. The pilot protocol is adequate for collecting observed field conditions associated with perennial flow. Adjustments and additions are necessary for

the Phase 2 effort; the most important are the inclusion of the channel head in all future surveys, random selection of study areas and survey routes, closer oversight of field parties, and more consistent QA/QC.

2. Observed basin areas are smaller than the FFR default basin areas. Median observed basin areas above the Np/Ns break (Pd) for the Eastside, Westside, and Coastal FFR default regions are 36, 7, and 2 acres, which are less than 15 percent of the FFR default basin area, and the average observed basin areas are 118, 24, and 8 acres, which are less than 61 percent of the FFR default basin areas. Comparison of observed basin areas to default basin areas is complicated by uncertainty over the whether the default values represent averages, medians, or some uncalculated and negotiated value.
3. Considerable variability was observed among basin areas. Observed basin areas differ significantly between FFR default regions. Average annual precipitation classes appear to provide a better means of stratification than either present default regions or ecoregions.
4. No channel characteristics were found to be reliable field indicators of the Np/Ns break. However, either the channel head or the distance downstream from channel head appear to be suitable field indicators and distance down slope from the basin divide may be a suitable map-based indicator.
5. The sample size required to estimate the average basin area with a 90% confidence interval and 10% precision depends on the stratification criteria. Assuming three cells (e.g. Eastside, Westside, Coastal) within the strata (e.g. FFR default regions or precipitation classes), the present FFR default regions and proposed precipitation class default regions require a minimum sample of 300 sites whereas, the use of distance downstream from divide to Pd as an alternative default criterion, requires a minimum sample of 30 sites.

If a statewide demarcation study with similar research objectives is pursued, insights from the 2001 pilot study support the following:

1. Utilize a field protocol similar to that used in 2001 with minor changes to include the channel head, debris-flow categories, and valley width.
2. In determining the survey route, randomly select the tributaries to be followed.
3. Stratify by average annual precipitation categories that would extend across the state.
4. Provide “equal probability” sampling from the population of N streams within each stratum.
5. Assess the adequacy of using other metrics as default criteria, e.g., channel head, seasonal stream length, or distance from divide.
6. Select a sample size that will provide the desired precision level.
7. Provide closer oversight of the field parties to insure consistent application of the protocol.

Expansion or modification of the scope of future studies beyond the demarcation focus of the pilot phase (e.g. in-channel habitat and functions) is feasible but will likely require additional changes to sampling approaches and field protocols.

TABLE OF CONTENTS

SECTION 1. INTRODUCTION TO REPORT

This document presents the results and recommendations of the Type N Stream Demarcation Pilot Study conducted by the Np Technical Group for the Cooperative Monitoring, Evaluation, and Research Committee (CMER) of Timber, Fish, and Wildlife (TFW). It is the first phase of a planned two-phase demarcation study to collect data to "refine the demarcation between perennial and seasonal Type N streams" (Forest & Fish Report, Schedule L-1). This phase of the study was designed to test the field protocol for use in the second data-collection phase and to obtain sufficient basin area data to estimate the sample size required for the second phase. The need for the second phase will be determined by the TFW Policy Committee (Policy).

This report has been reviewed and revised twice. The first review was by a CMER committee that revised the original report in mid-2003. The CMER report was submitted to Policy and Policy requested CMER to submit the report to the Scientific Review Committee (SRC) for review. The SRC returned three reviews (Appendix J) in September 2004. The CMER report was revised following SRC recommendations as outlined in the CMER-approved Action Plan (Appendix K) in December, 2004, resulting in the present version 7.5

The pilot study began as an effort to develop a field protocol and to test its adequacy while collecting sufficient data on basin area variability to determine a sample size for the following phase of the study. During the development of the scope of work for the pilot study, a set of hypotheses was developed to explore the ramifications of the data. The relative importance of the two aspects of the pilot study changed during the testing of these hypotheses as the large discrepancy between default basin areas and observed basin areas became apparent. Preliminary findings indicated the observed basin areas were significantly smaller than anticipated.

STUDY BACKGROUND

Forests and Fish

The Forests and Fish Report (FFR) establishes a water typing system that identifies headwater streams, which do not contain fish habitat, as "Type N" waters (**Table 1)**. Type N waters are further subdivided into two categories:

- Perennial ("Np") segments that do not go dry (including "spatially intermittent" channels that contain short alternating wet and dry reaches); and
- Seasonal ("Ns") segments that go dry "in a year of normal rainfall" and are located upstream of the perennial reaches.

Table 1: FFR stream types

Type	Description
S	All waters within their ordinary high water marks inventoried as "Shorelines of the state."
F	All segments of natural water within bankfull widths containing habitat used by fish at any life stage and at any time of year.
N	All water that are not S or F that are either perennial or connected by an above ground channel to waters connected to F or S streams.
Np	Perennial: Type N waters that do not go dry at any time during "a year with normal rainfall."
Ns	Seasonal: Type N water that goes dry during " a year with normal rainfall."

These definitions (**Appendix A**) are in Chapter 222-16-030(3) and (4) in the Washington Administrative Codes (WAC). The FFR definition is unclear about the flow conditions necessary to qualify as an "Np" stream, e.g. continuous or discontinuous bodies of water, flowing or standing, open or piped channels.

The distinction between Type Np and Ns streams is important to rule implementation. Type Np streams are believed to provide habitat necessary to support the long-term viability of state-protected amphibians and water conditions that support harvestable levels of salmonids in downstream Type F (fish-bearing) streams (Gomi and others, 2002; Meyer and Wallace, 2001; May and Gresswell, 2003). For these reasons, the riparian areas along Type Np streams are given specific protections during forest practices (logging, road maintenance) that are not required for Type Ns streams.

Identifying the change from seasonal (Ns) to perennial (Np) waters, the Np/Ns break, is difficult except during the late summer-early fall, low-flow season. The following quote from the FFR Appendix B, 2 (iii) describes the anticipated problem of field identification and provides for an interim solution.

"*Making the determination [of the initiation point of perennial Type N waters] will require a better understanding of the natural variability of the spatially intermittent component of perennial streams. Factors such as stream associated amphibian habitat, sediment deposition patterns, channel morphology, water flow, non-migrating seeps or springs, and position in the basin will be observed in preparing a protocol for perennial stream identification. In those cases where non-migrating seeps or springs as the point of initiation of perennial flow cannot be firmly identified with simple, non-technical observations: (A) on the Westside, Type N waters will be "perennial streams" if they have a basin size in excess of the following minimums: 13 acres in the coastal zone … and 52 acres on the rest of the Westside; and (B) on the Eastside, Type N waters will be "perennial streams" if they have a basin size in excess of 300 acres*."

The extent to which field identification vs. basin area defaults are used as the regulatory water typing method is unknown.

The basin area defaults were developed from limited, unpublished field data collected by volunteers during the Forest and Fish negotiations in 1998. Some of the pre-2001 studies are summarized in **Appendix B** (Pre-2001 Studies) and their results presented in **Table 2**. Of the data discussed during the 1998 rule negotiations, only the Kapowsin data were documented. Therefore, the default basin area does not reflect the numbers in **Table 2**. The FFR authors recognized the scientific uncertainty underlying the selected default basin areas by placing this study in Schedule L-1 of the FFR.

Table 2: **Previous Studies**. Results of pre-2001 field studies to assess default basin areas. Of these only the preliminary Kapowsin data were available during the 1998 FFR negotiations. See summary report in **Appendix B**.

Study Area	Basin Areas (acres)	
	Average	Median
Kapowsin	41	17
SW Washington	20	13
Mid-Columbia	90	32
Chelan	68	39
Stillman Basin	11	10
Skagit	23	17

CMER, which is responsible for assessing the effectiveness of the rules, identified this issue as a top priority for adaptive management efforts and approved funding the project in fiscal year 2001. The Upslope Processes Scientific Advisory Group

(UPSAG) is responsible for managing the project and established the *ad hoc* "Np Technical Group" in June 2001 to manage the process and provide technical guidance.

Study Development

The Np Technical Group developed a pilot study protocol (Perennial Stream Survey Field Sample Protocol, version 1.21) to guide data collection during the August to October 2001 field season. The ten CMER cooperators listed in **Table 3** collected field data using the pilot study protocol from a total of 234 surveys in 224 headwater basins in both Eastside (300 acres) and Westside (52 acres) FFR default basin regions (**Figure 1**). The Coastal FFR default region (13 acres) was not specifically targeted during the pilot study but one Westside study area

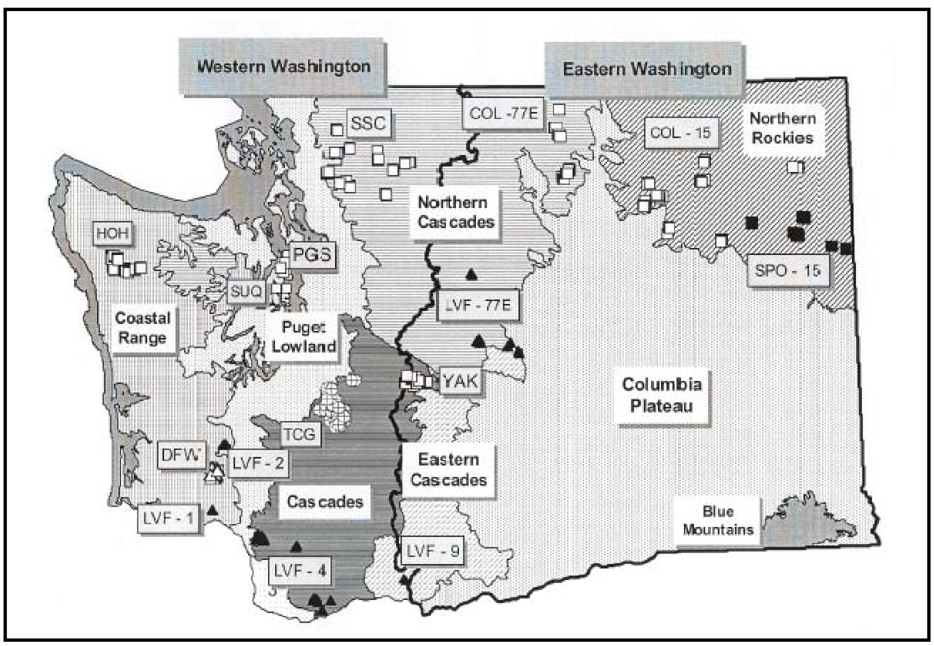


Figure 1: Location of study areas and USEPA Level III Ecoregions in Washington. The 15 study areas are identified by cooperator code (Table 3) and by ecoregion number. The heavy north-south line is the Cascade crest; it divides the state into Eastern Washington (Eastside) and Western Washington (Westside) FFR default regions. The Coastal spruce zone FFR default region is not shown but occurs as a band along the Pacific coast.

Table 3. **Cooperators providing field data** for the 2001 Type N Demarcation Study by name and code. The surveys provided by each cooperator are classified by location, survey type, and information provided. The total sample size available for different analyses varies with survey type, provided information, and basin delineation. Terms and procedures are described in the text. *The HOH study area includes both the Coastal and Westside default regions and in some analyses are included in both regions.

Cooperator	Study Areas		Survey Type					Surveys including Transition Points			Surveys for which Basin Areas were Delineated		
	FFR Default Region	Eco-region	Total	Initial	Repeat (Surveys / Sites)	Single Thread	Total Tributary (Surveys / /Sites)	Pc	Pd	Ch	Pc	Pd	Ch
Colville Confederated Tribes (COL)	E	15	7	7		7		7	6	0	6	5	0
	E	77E	6	6		6		5	6	3	5	6	3
Department of Fish and Wildlife (DFW)	W	1	42	34	8/3	29	5/2	31	37	37	18	23	24
Hoh Tribe (HOH)	C*	1	22	22		22		19	22	18	17	19	12
Longview Fibre Co. (LVF)	E	77E	15	15		15		14	15	11	10	12	9
	E	9	2	2		2		2	2	0	2	2	0
	W	1	2	2		2		2	2	0	2	2	0
	W	2	4	4		4		4	4	3	4	4	3
	W	4	16	16		16		16	16	9	16	16	10
Port Gamble S'Klallam Tribe (PGS)	W	2	4	4		4		4	4	3	1	1	0
Spokane Tribe (SPO)	E	15	6	6		6		5	6	0	4	6	0
Skagit System Cooperative (SSC)	W	77W	27	26	1/1	21	5/2	26	26	25	21	23	22
Suquamish Tribe (SUQ)	W	2	7	6	1/1	6		6	6	3	6	6	1
The Campbell Group (TCG)	W	4	61	61		61		54	61	28	50	57	20
Yakama Nation (YAK)	E	4	13	13		13		13	13	12	13	12	12
TOTAL	**3**	**7**	**234**	**224**	**10/5**	**214**	**10/4**	**208**	**226**	**152**	**175**	**194**	**116**

includes the boundary with the Coastal default region and was placed in that region to estimate its parameters. Coordinated training and quality control/assurance (QA/QC) programs were implemented on a limited basis because of time constraints.

An analytical protocol was developed during the fall and winter of 2001 and collation and analysis of the field data began in February 2002. The purpose of the analytical phase was to evaluate the 2001 pilot study protocol and the 2001 field data.

PILOT STUDY PURPOSE

The dual purposes of the pilot study are (a) to test a field protocol for collecting data on the initiation of perennial flow and (b) to collect sufficient data to assess basin area variability for use in the design of a statewide data collection effort envisioned to follow this pilot study. The objectives that achieve these purposes are listed in **Table 4.**

Table 4: **Objectives** of the Type N Stream Demarcation Study: pilot Phase.

1. Develop pilot field and analytical protocols for the collection and analysis of field observations.

2. To assess the:

- Adequacy and replicability of the pilot protocol.
- Variability of basin areas and other parameters.
- Basin and channel attributes that are potentially useful in defining the Np/Ns break.
- Refine protocols for the statewide study.

ASSUMPTIONS AND DEFINITIONS

A few key definitions and assumptions are necessary to assess Type N flow regimes and basin areas. Type N portions of streams are found above the uppermost extent of fish habitat, as defined in WAC 222-16-030(2) for Type F waters, and extend upstream to the channel head (**Figure 2**). As such, they are usually the smallest streams with few or no tributaries.

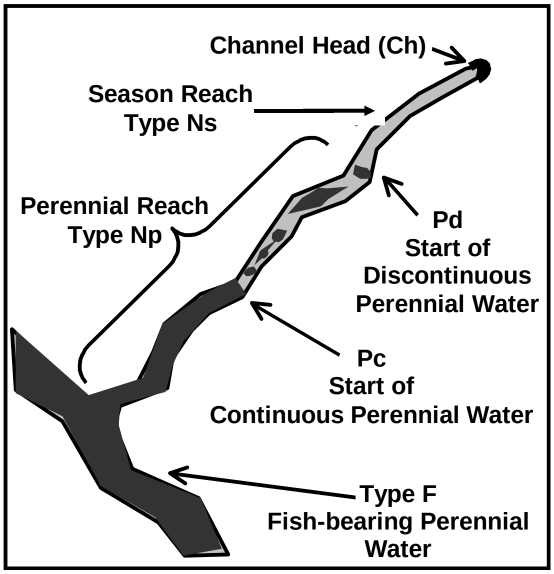


Figure 2: FFR water types and hydrologic points. The FFR water types are based on the distribution of fish habitat (Table 1). The hydrologic points define the limits of the seasonal and perennial water types.

Definitions

Hydrologic Points

The demarcation study includes three key hydrologic points that break flow conditions within a headwater stream (**Figure 2**):

Ch: The channel head is the highest observed point of channel incision or scour that separates unmodified forest floor from the channel. Ch marks the headward extent of flowing surface water with sufficient energy to erode a channel into surficial materials (Horton, 1945; Dunne, 1980). The pilot phase did not require cooperators to collect Ch data and it is important to this study because only surveys that reached Ch are assured to have properly identified the true Np/Ns break.

Pd: The highest observed point of perennial water (may be continuous or spatially intermittent [discontinuous], flowing or standing). The Pd is also the lowermost point of the continuously dry, seasonal (Type Ns) channel downstream from the channel head. Pd marks the headward extent of seepage in sufficient quantities to maintain storage in alluvium, dry season evapotranspiration, and small disconnected bodies surface water (Clement, 2003).

Pc: The highest observed point of continuous perennial water (may be flowing or standing). Pc was verified by a downstream survey to either the junction with Type F waters, or 200 meters whichever came first. Pc marks the headward extent of sufficient groundwater recharge to the channel to maintain continuous surface flow.

Channel Terms

The hydrologic points divide the channel into three reaches including one or more segments (**Figure 2**).

Reach: A portion of the channel having similar hydrologic characteristics. The reaches used in this report include:

Seasonal: The headward portion of the channel that goes dry during years of normal rainfall. It occurs between hydrologic points Ch and Pd.

Discontinuous Perennial: The headward portion of the channel that contains small (~5 cm) to large bodies of standing or flowing water throughout the year. It occurs between hydrologic points Pd and Pc and is Type Np waters.

Continuous Perennial: The portion of the channel that contains a mostly continuous body of flowing or standing water. It may contain dry segments as long as five meters (~16 feet) and occurs downstream of hydrologic point Pc and is Type Np waters.

Segment: A portion of the channel with similar flow characteristics identified during the pilot survey for purposes of description. Segment breaks occur at a change in flow characteristics or every 30 meters (98 feet) whichever is less.

Drainage Basin Terms

Drainage Basin: The drainage basin is the area that contributes water to a selected portion of a stream network (**Figure 3**). The term may refer to either surface water (watershed) or to subsurface water (soil and/or ground water). It is separated from adjacent drainage basins by the stream divide. Two drainage basin areas are referred to in this study: the *default basin area*, which is specified in the FFR (see quote on page 3) for a state default region and the *observed basin area,* which is the area delineated and measured on topographic maps in association with one or more study streams based on data provided by this study.

Stream Divide (Divide): The line of highest elevation on the land surface between adjacent drainage basins that separates surface water flowing toward one stream from that flowing toward the adjacent stream.

Subsurface Divide: The line of highest elevation on the top of the saturated zone between adjacent subsurface drainage basins that separates soil and/or groundwater flowing toward one stream from that flowing toward the adjacent stream (**Figure 3**). It may or may not coincide with the stream divide. Perennial waters require sufficient subsurface storage capacity to deliver water to streams for the duration of the dry season (Asano and others, 2002; Smakhtin, 2001).

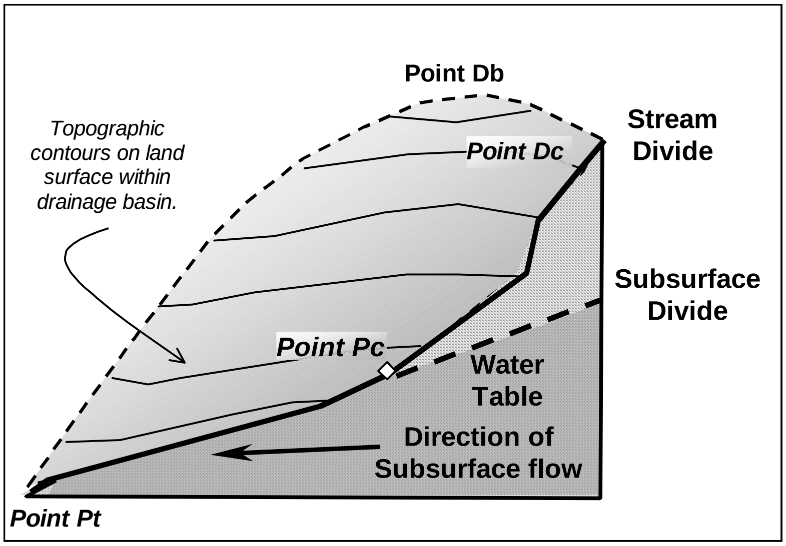


Figure 3: Block diagram showing the assumed relationship between surface and subsurface drainage basins. The subsurface divides are assumed to coincide with the surface divide with the subsurface water discharging to the stream to maintain perennial flow. The water table is shown intersecting the channel bed at Pc (the beginning of continuous perennial flow) but it may intersect the channel bed farther upstream at Pd (beginning of discontinuous perennial flow), which is not shown.

Data Stratification

The survey data from 224 sites (**Table 3**) were pooled into three progressively larger groups for analysis. The fundamental grouping for analysis was the study area and for assessing FFR default values the grouping was the default region. Ecoregions were a convenient grouping for study areas to assess spatial variability.

- **Site**: the location of an initial stream survey. A site may contain one or more (if surveys were repeated) surveys. A site includes the area encompassing the survey route, the downstream extension of the surveyed stream to its confluence with a larger tributary, and the delineated basin areas. A total of 224 sites have one or more surveys.
- **Study Area**: A study area consists of randomly distributed sites provided by one cooperator and located within one ecoregion. This distinction is necessary because three cooperators provided survey data from sites in more than one ecoregion (Longview Fibre Corporation - LVF, Colville – COL - and Spokane Tribes - SPO) and the number of surveys within a study area is variable. The distribution of the 15 study areas appear in **Figure 1**. Study

areas were randomly sampled and their summary statistics should be representative for the study area. For this reason study areas were used to test for variation within and between ecoregions and FFR default regions using ANOVA.

- **Ecoregions**: Washington is divided into eight level III ecoregions by the EPA (**Figure 1**). Level III ecoregions are based on the analysis of the patterns and the composition of the vegetation, wildlife, and physical phenomena (geology, topography, climate, soils, land use, and hydrology) that affect or reflect differences in ecosystem quality and integrity (Omernik 1987, 1995). Study areas are located in seven of the eight ecoregions.
- **FFR default regions:** FFR divides the state into three default regions for which default basin areas are specified (**Figure 1**). Study areas occur in the 300-acre (Eastside) default basin region and the 52-acre (Westside) default basin area. No study area occurs exclusively in the 13-acre default region (Coastal). However, the HOH study area in Ecoregion 1 encompasses both the Westside and Coastal default regions (three study sites) and for the purposes of this study the HOH data are included in both the Westside and Coastal default regions.

Watershed Attributes

Watershed attributes are topographic variables that further describe the observed drainage basin and are measured from topographic maps and DEMs using ArcView. These variables are included as parts of the search for channel or basin attributes that are potentially useful in defining the Np/Ns break. They are measured, in meters, from the Np/Ns break (Pd) as shown in **Figure 4** and are defined as follows:

- <u>Divide Distance</u> is the map distance measured perpendicular to the topographic contours along the valley axis between point Pd and the divide at the point where the valley trace intersects it (point “Dc” in **Figure 4**) and referred to as Pd-distance.
- <u>Basin Width</u> is the average width of the drainage basin as estimated by dividing the observed Pd-area by the Pd-distance and is referred to as Pd-width (the half width estimates the average length of hillslopes in basin);
- <u>Basin Relief</u> is the height of point Dc above point Pd and is referred to as Pd-relief.

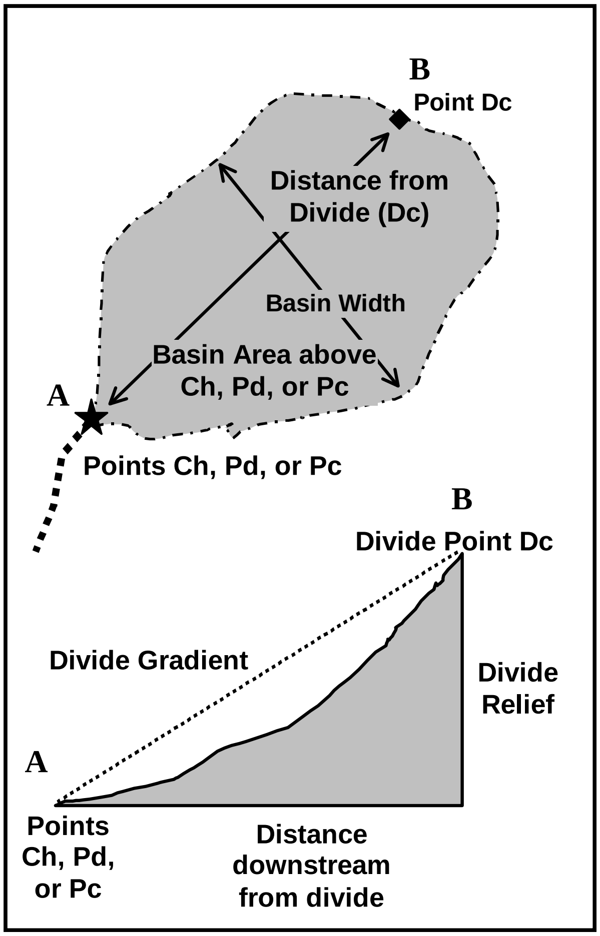


Figure 4: Watershed variables. Variables used to estimate the size of the subsurface reservoir maintaining perennial flow.

- Divide Gradient is the ratio of Pd-relief to Pd-distance and is referred to as Pd-gradient.

Assumptions

Drainage Basin Assumption

An implicit assumption underlying the use of basin area defaults in the FFR rules and this study is that for any perennial stream the subsurface divide and stream divide coincide. The drainage basin assumption allows the use of topographically defined default drainage basin areas to estimate the location of the Np/Ns break, which is probably controlled by discharge of subsurface water to the channel. Numerous studies have shown that drainage basin area is an important hydrologic control on perennial flow although other factors must also be considered (Smakhtin, 2001).

The drainage basin assumption may be reasonable for drainage basins located near primary drainage divides from which the land slopes away in both directions toward major streams. In these locations, the potential for subsurface inflow under the divide is probably low. However, the drainage basin assumption may not apply to all drainage basins (Freer and others, 1997). For instance, drainage basins located lower in the landscape where the potential for groundwater inflow along a variety of routes from areas higher than the secondary divides is possible (Winter, 1999). These relationships are shown schematically in **Figure 5**.

Where subsurface inflow to channels occurs at springs and seeps the location of points Pd and Pc are controlled by these features and their seasonal migration

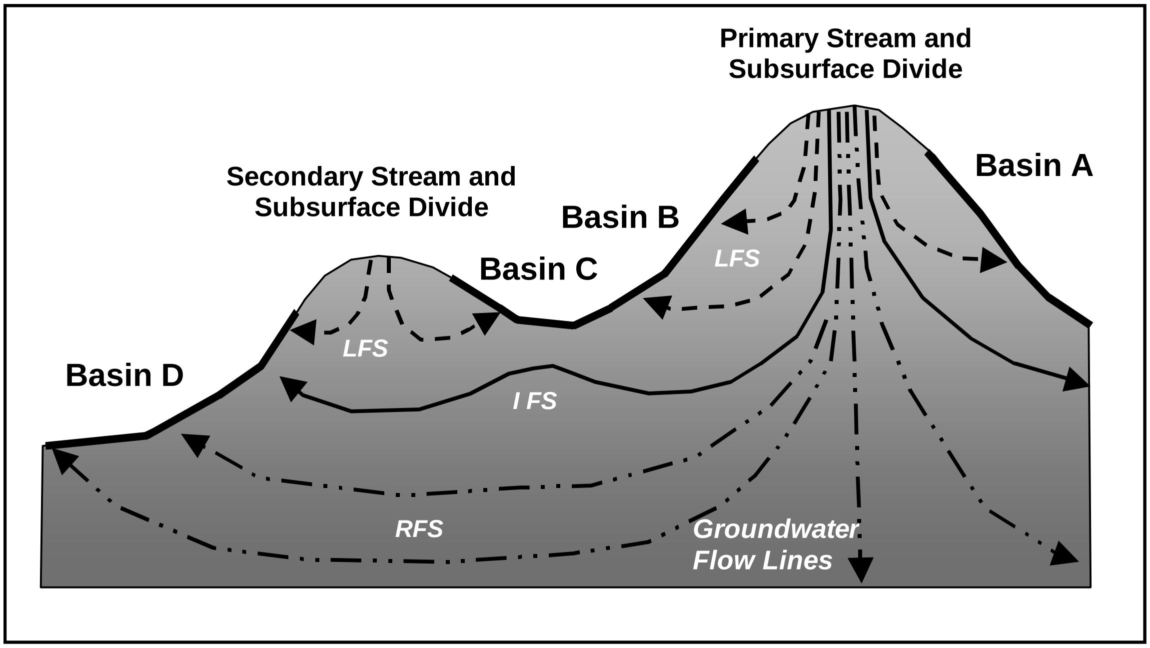


Figure 5: Groundwater flow regimens. A large dissected upland between two major rivers may support a complex groundwater flow system consisting of local flow systems (LFS) between hillslope and adjacent tributary stream [Basins B and C]; the intermediate flow systems (IFS) that may extend under local divides to discharge into a distant tributary stream [Basin D]; and the regional flow system (RFS) that extends from the major divide to the major stream [Basin D] and passes under local and intermediate divides.

inhibited. Some of these springs and seeps may be discharging groundwater that has flowed under the surface divide from upslope drainage basins.

Basin Delineation Assumptions

Two assumptions are necessary to determine and outline the boundaries of drainage basins on a topographic map – the topographic assumption (**Figure 6a**) and the symmetric basin assumption (**Figure 6b**). To the extent that these assumptions do not apply to the surveys within a study area, the statistical variability in basin areas and distances downstream increase for that study area.

The topographic assumption is that the topographic map accurately displays the location of stream channel and drainage divides in the vicinity of the study site. This assumption is necessary when using USGS topographic maps and digital elevation models (DEMs) as base maps on which to locate points and delineate basin divides.

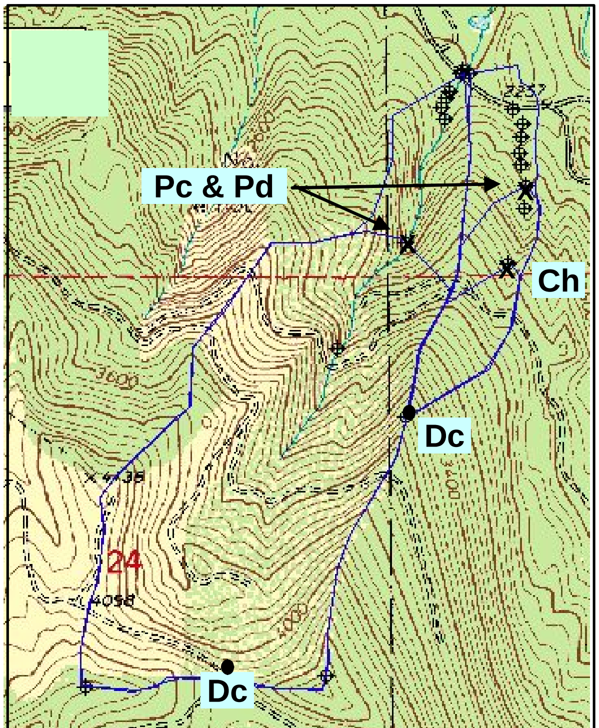


Figure 6A. Symmetric basin assumption. The stream divides for these study sites is drawn perpendicular to the topographic contours and symmetric to stream at points Pc, Pd, and Ch. The cooperator (TCG) provided a series of GPS points along the survey route that include Pd and Pc for both basins and Ch in one basin only. In the strongly defined topography of the Kapowsin tree farm, divides are easily and accurately delineated from topographic data. In lower relief areas, divide delineation becomes more difficult as illustrated in Figure 6B. Abbreviations defined in text.

The topographic assumption may not be valid for small streams that are unconfined, in valleys of low relief, and/or under a dense forest canopy (Meyer and Wallace, 2001). When the relief is too low to cause an undulation in the forest canopy, either the channel location and/or divides may not appear on the topographic map or their location, continuity, or configuration may be inaccurate. An example of this problem for a small, shallow valley on extensive side slopes of the Skagit River Valley is shown in **Figure 6b**.

The symmetric basin assumption is that the drainage divides above points Ch, Pd, or Pc extends upslope perpendicular to the contour lines on both sides of the valley as shown in **Figure 6a**.

The symmetric-basin assumption is not valid when the stream heads in a valley-side seep or spring. In this case, the drainage basin extends toward the divide on only one side of the valley.

Year of Normal Rainfall

Perennial Type N streams are defined in FFR as those that "do not go dry in a year of normal rainfall," though no definition of "normal rainfall" is provided. The precipitation for the 2001 water year (October 2000 through September 2001) can only be approximated for the study areas because of the lack of area meteorological stations. Based on the closest meteorological stations the 2001 water year precipitation is estimated to be around 85 inches for study sites in the Coastal region, 30 to 40 inches for most sites in the Westside and 8 to 15 inches for most sites on the Eastside. Westside and Eastside study areas located in the

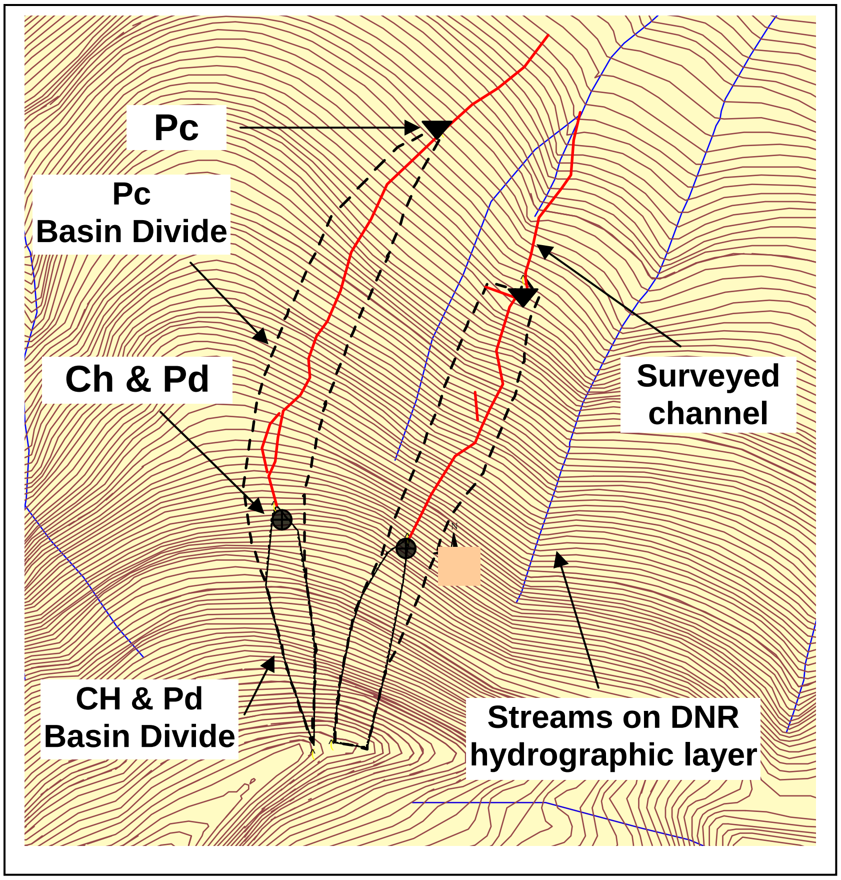


Figure 6b. Survey sites showing the discordance between surveyed streams and topographic contours on USGS 10-meter DEM. The surveyed streams follow lie in shallow valleys that do not appear beneath the dense forest cover. The hydrographic layer produced by the Washington Department of Natural Resources from aerial photographs and used for regulatory purposes shows a similar discordance to the topographic contours. (SSC sites 83W & 83A)

Cascade Range received more precipitation, around 50 to 60 inches. The pilot-study data must be evaluated with respect to "a year of normal rainfall" and interpreted accordingly. The analysis of the 2001 water year, which is presented in the Results section, indicates that the water year was unusually dry but that the summer months on the Westside were unusually wet.

Temporal Variability

The pilot study is confined to the 2001 field season and most basins were surveyed only once during 2001. As such, the data presented here are a snap shot in a continuum of seasonal and annual changes in stream discharge. This continuous variation in discharge can be assessed by investigating intra-annual and inter-annual variations in the surveyed basins.

Intra-annual variations describe the change in discharge in the headwater basins during the course of one year in response to seasonal variations in precipitation. Intra-annual (or seasonal) variations can be assessed by repeated surveys of the drainage basin from the end of one rainy season to the beginning of the next. The pilot protocol did not require cooperators to conduct repeat surveys although three cooperators (SUQ, SSC and DFW) conducted two or more repeat surveys in five basins. This sample is too small for analysis but it can be used to illustrate the temporal variability in Pc or Pd location.

Inter-annual variations describe the between year variations that result from variations in annual precipitation. Stream discharge regimens should differ between drought and wet years. These variations gave rise to the concern that the default drainage basin areas may not reflect conditions during a "year of normal rainfall." Inter-annual variations require repeat surveys of the same basin conducted at the same time of successive years. Inter-annual monitoring was not possible during a one-year project.

SECTION 2. METHODS

Field Data

Field data were collected following procedures (**Table 5**) in the pilot study protocol (**Appendix C**). Training and field assistance services were provided to tribal cooperators, other cooperators if requested, through the Northwest Indian Fisheries Commission (NWIFC). These services were designed to reduce potential variability in data collection and to identify the parts of the protocol producing the most problems. Time constraints precluded comprehensive protocol training for all cooperators.

Task	Procedure	Discussion
Sample Site Selection	Identify Type F/N breaks within study area; number breaks and select using a random number generator	Study sites are limited to lands managed under Forest Practice Rules. Other options to randomly select stream segments are available.
Identifying Survey Starting Point	Select a point on the sample stream with continuous perennial flow to mouth or where at least 200 m of continuous flow is visible. Select an easily identifiable point, such as a culvert, and survey upstream from this point.	Survey may be conducted in an upstream or downstream direction. Upstream is preferred direction.
Survey route (Selecting Tributaries)	In the Main Thread Survey, select the tributary with either the highest flow category or the highest channel category (see definitions in Appendix B). When tributaries are identical, flip a coin to select right or left tributary and alternate tributaries in further cases.	Two survey types possible – Main Thread and Total Tributary. In main thread only one channel is followed to head, In Total Tributary all tributaries upstream from the Type F/N break are surveyed.
Channel Segment Identification	New channel segments begin at changes in flow category, confluence with a tributary, or 30 meters, which ever is shortest.	At each change in channel segment, data on segment length and channel geometry and characteristics are recorded for the segment just surveyed. Features to be recorder are listed in Appendix B.
End Point Determination	Survey ends after 200 m of dry channel or the channel head are encountered.	Surveys were not required to continue to the channel head or to record the channel head if it was encountered.
QA/QC	Repeat surveys at different times, or with different crews, and by continuing to head of channel	Three survey components tested: 200 m distance, flow changes within sample period, and between crew variability

Table 5: Summary of the 2001 pilot protocol. The complete protocol appears in Appendix C.

Study Site Selection

Cooperators were free to choose one or more study areas according to their own selection criteria. Within each study area, the sites were randomly selected using the following procedure; the streams are numbered at one of the following locations:

1. Confluence between Type F and Type N streams
2. Intersection between streams and section boundaries

3. Confluence of second order streams
4. Previous stream surveys

Then, streams were selected using a random number generator. A few study sites were selected as being representative of the area and some were revisited basins from previous studies.

Survey and Segment Description

The intent of the survey was to identify points Pd and Pc and to describe the channel reach between them. To meet this intent, procedures were specified in the pilot study protocol for determining the survey type, direction, and route as well as for assuring the inclusion of the highest perennial water (point Pd) and the highest continuous perennial flow (point Pc). Each is covered here.

Two types of surveys are specified in the pilot study protocol – the Main Thread and the Total Tributary. The main thread survey was the project norm (**Table 3**) but each field party was encouraged to include one or more total tributary surveys. In the main thread survey, only one channel is surveyed whereas, in the total tributary survey, all non-dry tributaries are surveyed upstream from point Pc. The method for selecting tributaries to be included in the survey route depends on the survey direction.

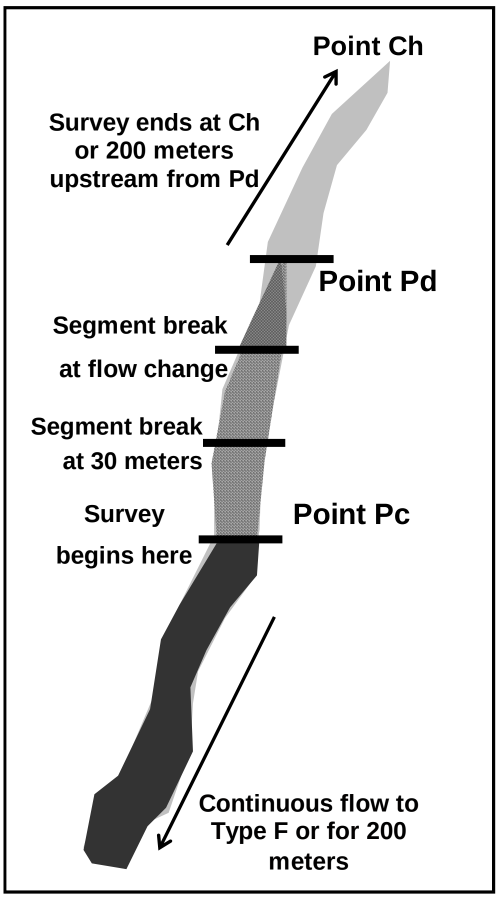


Figure 7: Survey reference points. Type N stream showing the requirements for survey end points and segment breaks at 30 meters or change in flow category.

The route followed by the field parties could be either in an upstream or downstream direction. Each direction had a different protocol for selecting tributaries to include in the survey. In the upstream survey, the channel with the higher flow category (see **Table 6** for flow categories) was to be followed; if two tributaries had similar flow categories, the choice was to be made by coin toss. Upstream from the first coin toss the selection of similar-flow tributaries is to alternate between right and left. The downstream selection method simply follows channels downstream to Pc. Some downstream surveys chose the initial channel head using the upstream selection method.

To assure inclusion of the highest perennial water (Pd) and the start of continuous perennial flow (Pc), the survey was to extend 200 meters (565 feet) upstream from the highest observed point of perennial water (Pd), which could be either spatially discontinuous or continuous flow, and 200 meters (565 feet) downstream from the highest point of continuous perennial flow (Pc) (**Figure 7**). The stream channel within the survey was subdivided into a series of segments for data collection and analysis. Segments were 30 meters long (~100 feet) unless a change in flow category (**Table 6**) reduced that length.

Table 6: **Segment Data**. Descriptive data required for each segment in a survey. Data are to be recorded at a segment break for the segment just completed.

Flow Category	
Flowing Water (FW)	Dry (D)
Standing Water (SW)	Unknown (U)
Flowing Pocket Water (FP)	Obscure (O)
Standing Pocket Water (SW)	
Channel Category	
Defined Channel (DC)	Piped Channel (PC)
Poorly Defined Channel (PDC)	No Channel (NC)
Modified Channel (MC)	
Channel Geometry	
Bankfull Width (BFW)	Upstream Gradient (%)
Bankfull Depth (BFD)	Downstream Gradient (%)
	Mean Segment Gradient (%)
Dominant Substrate	
Fine-grained [silt/muck/mud] (F)	Cobble (C)
Sand (S)	Boulder (B)
Gravel (G)	Bedrock (R)
Associated Features	
See Table 7	
Tributary Changes	
Record Flow and Channel categories	

Segment Observations

At each segment break, the field observations were recorded on the field data sheets (**Appendix C**). The geomorphic and hydrologic data collected for each segment are listed in **Tables 6** and **7** and described in **Appendix D**. Detailed

Table 7: Associated Features. List of features that could occur at flow-change segment breaks and be a potential cause of the flow change.

Spring (SP)	Gradient Break (GB)
Seep (SE)	Debris Slide (DS)
Wetland (WT)	Substrate Change (SC)
Wet Site (WS)	Road Crossing (RC)
Beaver Pond (BP)	Road Drainage Input (RD)
Perennial Tributary Junction (PJ)	Diversion (DI)
	Other (OT)

segment data were collected to (1) search for possible field indicators of the Np/Ns break and to aid in the identification of Pd using the field records.

Segment data were collected using reconnaissance-level procedures that would be similar to those used by practicing foresters searching for Pd:

- Bankfull width and depth were measured at one or two representative channel cross sections within a segment using a fiberglass tape, stadia rod or other common measuring devise.
- Segment gradient was measured at the segment break by upstream and downstream shots using a clinometer or by laser rangefinder from one segment break to the next.
- Dominant substrate was visually estimated for the segment.
- Geomorphic features that could affect the segment hydrology were visually identified at segment breaks created by changes in flow category (**Table 7**) and recorded where present.

Data Submission

To insure uniform and consistent data entry, the field data were recorded, collated, and submitted on 2001 Data Entry Forms (**Appendix E**) following the definitions in the 2001 Data Dictionary (**Appendix D**)). All submitted data were included in the pilot analysis. Data from incomplete surveys were included to the extent that their applicability could be determined.

GIS Data

The topographic and environmental data listed in **Table 8** were extracted for each study site from GIS layers using ArcInfo and ArcView. GIS data were provided by:

- Cooperators -- point locations and some basin area delineations;

- The Washington Department of Natural Resources-- Data layers listed **Table 8**
- CMER staff geomorphologist – located additional points and delineated most stream divides in the ArcView format.

Table 8: GIS data layers used to describe site characteristics.

GIS Layer	Description
USGS Topographic Maps	Scanned and georeferenced 1:24,000 topographic quadrangles; served as base maps for locating field points and measuring areas and distances.
DEM Data	Digital elevation models of the topographic maps at a 10-meter resolution. Used to determine elevation of points.
EPA Ecoregions	EPA Level III Ecoregions; used as a stratum for classifying site locations.
PRISM Precipitation Layer	Estimated average annual precipitation at points within survey sites.
DNR Stream Layer	Streams digitized from USGS topographic maps and aerial photographs and identified by a unique number.
DNR Soils Layer	Forest soil map interpreted for texture and used to categorize sites.
DNR Geology Layer	Digitized geology map of state at 1:100,000 that was interpreted for lithology and used to categorize sites.

GIS Procedures

The GIS portion of the analysis occurred in four steps:

1. ***Point Plotting***: Coordinates for Pd, Pc, and Ch were provided by cooperators and transformed to UTM coordinate system by Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) and plotted on the GIS topographic base maps (**Figure 6**). These point locations were adjusted as necessary to align them with the channel or valley floor shown on the map. The locations of the adjusted GIS points were compared to those on hard copy maps provided by the cooperator whenever possible. Seventeen of the 224 surveys were omitted when they could not be located by the given coordinates and no topographic map was provided by the cooperator (**Table 3**);

2. ***Basin Area Delineation*****:** Drainage basins were manually delineated by identifying their stream divides on topographic maps. The stream divides were defined by lines drawn perpendicular to the elevation contours and through the highest elevations, as shown in **Figure 6b**. In 12 of the 207sites either Pd or the drainage divide was not apparent on the topographic map and no basin area could be delineated (**Table 3**). Once the drainage divides were delineated, point Dc (the point where the stream trace intersects the divide) was located and added to the point data set. Manual delineation was used after attempts at delineation by GIS algorithms failed.

3. ***GIS Measurements***: The areas of the delineated drainage basin were determined using the "ReturnArea" function in ArcView. Distances between points Dc and Pd were determined by drawing a line perpendicular to contours and along the valley floor between these points. The lengths were calculated using the "ReturnLength" function in ArcView;

4. ***Union with other GIS Coverages*****:** Elevation, precipitation, and ecoregion information was extracted for Pd and Dc using the DEM, PRISM precipitation, and USEPA Ecoregion GIS layers. These data were transferred to the database for statistical analysis. The other GIS layers in **Table 8** were not used because: (1) The DNR hydrography layer was too inaccurate (see **Figure 6b**); (2) the soils and geology layers would be useful to analyze the underlying causes of basin area variability, which was considered beyond the scope of this initial phase.

Protocol Assessment

An important purpose of the pilot study protocol was to assess the adequacy and replicability of the pilot protocol. Replicability was to be assessed by having different parties survey the same stream and the variability arising from the application of its procedures and definitions was assessed by reviewing field training, assistance and replicate surveys as well as questionnaire responses from cooperators (**Appendices F and G**). Protocol compliance was also tested through statistical analysis of segment lengths, survey beginning and ending criteria, and success at recording requested data.

Qualitative data that could be used to assess the replicability and overall adequacy of the protocol included reports from tribal training, field assistance, and quality control surveys, a formal cooperator questionnaire (**Appendix G**), and information from review of data-entry materials. This qualitative analysis results in a list of recommendations.

Quantitative assessment of field data consistency and capture success was determined by means of statistical analysis. More specifically,

- "Consistency" estimates the degree to which the field parties could implement protocol requirements for segment length and survey initiation and ending.
- "Capture success" estimates the degree to which field parties could observe or, measure, and record the required field data in **Tables 6** and **7**.

The capture and consistency measures were calculated by the ratio of number of sites meeting the protocol requirement to the number of sampled sites. Whenever the ratio exceeds 90 percent, the consistency/capture is judged to be high. A rate less than 90 percent may indicate that a change in protocol, variable selection or definition, or training should be considered.

Data Analysis

This report emphasizes Pd because it is the hydrologic transition between Type Np and Ns water as defined in FFR and WAC 222-16-030(3). Pc and Ch data were obtained in the field to assure the capture of Pd and are presented only as necessary in tables, figures, appendices and text.

Several statistical routines were used. The statistical routines in Excel were used to calculate summary statistics, determine some correlations, and perform some ANOVAs. Routines in SAS, and SPSS were used to assess the channel and basin area data by analysis of variance (ANOVA), least squares regression, analysis of covariance, and Student's t-test. Summary statistics were calculated from the observed data pooled by study areas and pooled by FFR default region. A log transformation was used to normalize skewed distributions for statistical analyses. Because this is a pilot study seeking potential differences, comparisons are considered significantly different at the 90% level.

Although the survey areas were not selected according to a stratified sampling plan, the individual sites were grouped into study areas by ecoregion and default region strata to assess regional variability in the data. These groupings are referred to as "strata". The HOH study area includes sites from the Coastal and Westside FFR default regions. Because no other study areas lay within the Coastal FFR default region, the HOH study area is assigned to the Coastal FFR default region with the understanding that it may not be truly representative of that region (The HOH study area is also retained within the Westside FFR default region to more fully describe the variation within that region.) The variability of Pd-area was assessed by ANOVA to determine the degree to which the differences between Pd-areas within a study area are less than the differences between study areas when grouped by state, default region, or ecoregions.

Measure of Central Tendency

The measures of central tendency are the average and median of the data distribution and both are used in this study. In a skewed distribution, such as occurs in the pilot study, the median is the appropriate statistical measure of central tendency because it is less affected by extreme values (Haan, 1977). Skewed data are generally transformed such that the resulting distribution is approximately normal.

Since the pilot study data are approximately log normally distributed, a logarithmic transformation was applied before statistical computations (e.g. sample size, confidence intervals, and correlation testing) were performed. The log-averages, when transformed back into the original arithmetic values, correspond to medians (Evans et al., 1993). Thus, the results of these statistical analyses apply to the observed median values. Transformation also facilitates interpretation of customary descriptive statistical metrics, such as standard deviation, which lose their intuitive significance when applied to skewed data. Although the median is the most appropriate measure of central tendency in this study, the average is included in the text and tables. The uncertainty of which measure of central tendency the default basin areas represent requires that both measures be included.

Sample Size

The sample size required to estimate the log-transformed average of the observed basin areas in each FFR default region was based on the 90% confidence interval for the log-transformed average and several levels of precision. The approximate 90% confidence interval for the log-transformed average, which becomes the median when back-transformed, is estimated using a normal Z-statistic by:

$$\boldsymbol{Mean} \pm \frac{\boldsymbol{Standard\ Deviation}}{\sqrt{\boldsymbol{n}}} \bullet 1.65$$

This provides a method to estimate sample sizes needed to achieve desired precision levels defined by the relative size of the confidence interval by;

$$\boldsymbol{n} = \boldsymbol{CV}^2 \frac{1.65^2}{\boldsymbol{r}^2}$$

where ***r*** is the relative size of the confidence interval (i.e.

$\left(\frac{\boldsymbol{Standard\ Deviation}}{\sqrt{\boldsymbol{n}}} \bullet 1.65\right) = \boldsymbol{r} * \boldsymbol{Mean}\}$

and ***CV*** is the coefficient of variation of the population

$(\frac{\boldsymbol{Standard\ Deviation}}{Mean} * 100)$.

The sample-size equation has two inputs – the desired confidence interval of the transformed data (preliminary value of ±10%) and the coefficient of variation (estimated from the variability of available data). See **Appendix H** for further information on sample size.

Sample size was estimated from the pooled data for each FFR default regions because the sample data were distributed throughout the default regions. We assumed that the C.V. from the pooled data is most likely to approximate the maximum variance of the population under study, and therefore will produce a sample size sufficient to estimate the average of the true distributions. Because of this assumption, the estimated sample size should be considered as the minimum required in case the true variance was underestimated.

Alternative Field and Default Criteria

Alternate field and default criteria were sought at three different scales – channel, reach, and basin – to define the Np/Ns break. At the channel scale they were sought by comparing the values of channel characteristics at the Np/Ns break to those at other segment breaks. A potential field criteria for the Np/Ns break was considered to be a physical variable that occurred more frequently at the Np/Ns break than at other flow-category segment break (i.e. a segment break occurring at a change in flow category rather than the 30-meter length limit) or a change in the magnitude of a channel characteristic (e.g. channel depth or substrate) at the Np/Ns break that was different from the change that occurred at other flow-category segment breaks. At the reach scale, they were sought by comparing the location of the Np/Ns break to the channel head, and at the basin scale, they were sought by reference to the watershed variables in **Figure 4**. At the latter scales, a statistically consistent distance or height was sought.

Year of Normal Rainfall

Because "year of normal rainfall" is part of the FFR definition for seasonal and perennial flow, we evaluated the degree to which 2001 was "a year of normal rainfall." We assessed the degree to which 2001 was normal by analyzing annual and monthly precipitation during the field season and the preceding water year (October 2000 – September 2001) at NOAA long-term weather stations close to study areas, which were available through the Western Regional Climate Center. Monthly totals with more than three daily values missing were eliminated in most cases, as were water years with one or more incomplete months.

Annual and monthly precipitation values for the Water Year (WY) 2001 were compared to the quartiles of the long-term data. The following terms were applied to each quartile:

- First quartile (0-25th percentile): Unusually Dry
- Second quartile (25 – 50th percentile): Moderately Dry
- Third quartile (50 - 75th percentile): Moderately Wet
- Fourth quartile (75 - 100th percentile): Unusually Wet

The range contained within the second and third quartiles are interpreted as being "normal". This definition places half of all monthly and annual precipitation totals within the normal range. The quartile approach is useful for evaluating seasonal trends within the annual totals. Because the FFR is explicit in the use of rainfall to define normalcy, other variables, such as stream discharge, were not considered. In addition, we are not aware of forested headwater streams with active long-term gaging stations to allow analysis of stream discharge during the study.

Intra-Annual Variations

Three cooperators conducted one or more repeat surveys during the summer of 2001. The data on the changes in position of Pd and the size and abundance of different flow categories (**Table 6**) in the reach between Ch and Pc was summarized by:

1. Plotting the location of Pd downstream from Ch during each survey. This plot of distance downstream vs. time maps the seasonal migration of Pd.
2. Coding the flow categories in **Table 6** and then averaging the length-weighted flow categories by survey date. The plot of average flow category by survey date maps the changes in the wetness of the channel above Pc. The codes are:

Flow Category	Code
Flowing Water	10
Standing Water	5
Flowing Pocket Water	7
Standing Pocket Water	3
Dry	0
Unknown/Obscure	----

Inference Capabilities

Because cooperators chose study areas for their convenience, the study areas are not randomly distributed within either ecoregions or the FFR default region "strata". For this reason, statistical inferences based on pooled or combined data sets in these "strata" should be assessed using professional judgment.

Location of the channel head was not required by the protocol and thus was not captured in many surveys. Without its capture, the highest occurrence of perennial water may have been missed and the identified Pd in these surveys would thus be located downstream from the true Pd. This problem is believed to be concentrated in three study areas: TCG on the Westside and the SPO and COL in ecoregion 15 on the Eastside.

SECTION 3. RESULTS

Protocol Assessment

The pilot protocol (**Table 5** and **Appendix C**) was assessed for its adequacy and replicability and for the adequacy of the 200-meter survey beginning and ending criterion. The quantitative assessment is presented first and qualitative assessment second.

Quantitative Assessment

The quantitative assessment determines the degree to which the channel variables (**Table 6**) and associated features (**Table 7**) could be observed or measured and were recorded. The results are presented in **Table 9** for segment lengths and in **Table 10** for channel attributes and associated features. The quantitative assessment does not include replicability for which no quantitative data are available.

The pilot protocol specified both a minimum and maximum length for segments. Segment length should not exceed 30 meters and should not be less than the length specified for the flow category -- flowing water (FW), standing water (SW) and dry (D) segments requires a minimum of 5 meters; pocket water requires a minimum of 0.1 m if located between FW or SW. As shown in **Table 9**, the 75th quartile is 27.4 m of all segment lengths, which is within protocol limits. Few segments do not meet the length constraints -- 8 percent of the segments exceed the maximum length of 30 m and 10 percent or less of the segments with flowing water, standing water or dry are shorter than the minimum of 5 m.

Table 9. Segment Lengths. Segments are defined by changes in flow category but are not to exceed 30 meters or to be less than 5 meters (except for flowing or standing pocket water, which may be as short as 0.1 meter).

Statistic	Segment Length (m)			Short Segments by Flow Category (m)		
	All	Long (>30 m)	Short (<5 m)	Flowing	Standing Water	Dry
Number	3473	266	543	337	23	183
Median	11.3	31.1	2.5	2.8	1.1	2.1
Minimum	0.1	30.1	0.1	0.1	0.2	0.1
Maximum	389.4	389.4	5.0	5.0	3.7	4.9
1st Qtile	6.5	30.5	1.2	1.5	0.5	1.1
3rd Qtile	27.4	45.2	3.7	3.9	2.7	3.3
Percent of Sample	100%	8%	16%	10%	1%	5%

Table 10: Capture Rates. The percentage of field parties that recorded requested information at each segment break. The requested observations are listed in Tables 6 and 7.

Feature	Number Observed	Percent Captured by Field Parties
Segment Distance	3,611	100
Flow Category	3,565	99
Channel Category	3,559	99
Bankfull Width	2,723	75
Bankfull Depth	2,692	75
Upstream Gradient	2,255	62
Downstream Gradient	2,220	61
Segment Gradient	1,874	52
Dominant Substrate	3,183	88
Associated Feature #1	873	24
Associated Feature #2	57	2

Field notes indicate that segments exceeding the maximum length (30 meters) had steep gradients, waterfalls, slash, or impenetrable vegetation that resulted in the field parties not being able to access the channel for measurement. The compliance rate of greater than 92% for the maximum segment length indicates that compliance with maximum segment limits is high as are the compliance rates for the minimum segment length with flowing (90%), standing water (99%), and dry segments (95%).

The protocol clearly states the procedures and criteria for identifying the upstream extent of a survey. It requires that the survey continue upstream 200 meters (656 feet) beyond the last perennial water (Pd) or to the channel head (Ch) whichever came first. Field parties were not required to survey to the channel head or to record its presence if observed. For these reasons Ch was recorded in only 29 (13%) of the 224 complete surveys. In an additional 123 (55%) surveys, Ch was identified from descriptions in the field data sheets by the change in channel category to “no channel.” The channel head was neither recorded nor identifiable from field data in 72 surveys (34%) for a compliance rate of 66%. Many (47 %) surveys on the Eastside missed the channel head. Field records indicate that 152 of 224 surveys or 68 percent extended to the channel head and another 11 surveys or five percent extended a median distance of 165 meters from Pd (on the Eastside the protocol was interpreted to mean 200 m beyond Pc). The remaining 61 surveys or 26 percent did not continue pass the field identified Pd and the compliance rate for terminating the upper end of the survey is low at 74 percent.

The field parties could not consistently obtain the channel characteristics required by the pilot protocol. The capture rates for the channel variables listed in **Tables 6** and **7** range from low to very high. **Table 10** compares the number of identified segments (3,513) with the number of segments including a record for the requested field parameter. A high (>90 % success) capture rate occurs for segment length and for flow and channel categories. Lower capture rates (<75 %) occurred for bankfull width and depth, and gradient. Dominant substrate was captured 88 % of the time. Gradient is difficult to assess because some survey parties measured upstream and downstream gradient from each segment junction (clinometer method), and some parties recorded gradient between segment junctions (laser range finder).

Associate features have a low capture rate. The cause for this capture rate is difficult to assess for two reasons:

1. No option was provided to the field party to enter "Not present" when the features were actively sought but not found
2. Field crews were encouraged *not* to identify Pd in the field so as not to bias their observations, which likely limited the search for these features at Pd.

Qualitative Assessment

A protocol specification for each cooperator was two replicate surveys per study area by two different field parties. This requirement was not met. The short duration of the 2001 field season (and most cooperators only had one crew available) placed the cooperators in the position of either including additional study sites or replicating surveys. Every cooperator chose the latter option. The independent contractor (report in **Appendix F**) visited the tribal cooperators at least once for training and assistance purposes. The provision of consistent training and field assistance was believed adequate to promote consistency between these cooperators.

In late September quality control surveys were conducted with three tribes. The independent contractor surveyed a length of channel with the field crew (**Appendix F**). These replicate surveys identified several potential problems with replicability:

1. Interpretation of side channels
2. Identification of flowing vs. standing pocket water
3. Consensus of the minimum length of a segment defined by dry and standing pocket water.
4. The use of consistent 30 m segment lengths rather than flow-defined segment lengths
5. Identification of channel category in wetlands
6. Definition of channel category in channels with degraded banks

The QA/QC report and responses to the questionnaire (**Appendices F** and **G**) raised the following substantive issues about the adequacy of the pilot field protocol to fully capture and describe the Type N stream characteristics:

- Spatially intermittent flow categories should be combined, particularly the "Flowing Pocket Water" and "Standing Pocket Water" flow categories because they are difficult to distinguish
- Treatment of Piped Channel and Obscure Channel requires clarification.
- Bankfull width and depth are difficult to determine in the field because of indistinct channel edges.
- Gradients are oftentimes difficult to measure because vegetation obscures the channel and valley floor.
- Riparian vegetation should be substituted for upland vegetation in the site description.
- The minimum segment length should be specified for modified channels
- A standard for assessing dominant substrate is required to reduce subjectivity
- The distinction between seeps and streams requires clarification.
- The notation for standing water bodies within the survey, that is, what is the notation that be used when a pond occurs downstream from the channel head?

Data collation and analysis indicated the field protocol/data dictionary should emphasize the search for piped channels. Piped channels are channels that run under the substrate or forest debris. Flow is typically heard and occasionally visible through small holes in the substrate. Piped channels were encountered in 52 study sites on the Westside. Important hydrologic transitions were located within these channels --Pd occurred within a piped channel at 18 (35%) of these sites and Ch occurred within piped-channels at 9 (17%) of these sites. Identification of piped channels was not required by the protocol but was available as a channel category when observed.

The FFR does not include piped channels as a category of typed waters. Appendix B in the FFR indicates that Type N channels must be connected to Type F or S channels by 'above ground channels' but it does not place similar constraints on the Np/Ns break (Pd) or channel head. If in some future FFR revision, piped channels are defined as macropores and not part of stream channel Pd and Ch would be placed at the last expression of the open channel and be interpreted as a channel-head spring.

Some cooperators encountered segments that were scoured to bedrock by recent debris flows and lacked both an alluvial/colluvial valley fill and channel. These segments were designated "poorly defined channels" because of the lack of a more appropriate category. The addition of the channel categories – "debris-flow scoured" and "debris flow deposits" -- would facilitate the identification of these segment types and provide information on the distribution of valleys affected by debris-flows. The variation in alluvial thickness in debris-flow dominated reaches probably influences the position of Pd within them. As alluvium/colluvium fills the hollow, Pd should move down stream because the elevation of the channel will likely exceed the elevation of the water table resulting in subsurface flow rather than surface flow.

Although these difficulties likely contributed to some inconsistency between crews in the description of channel characteristics, they were not thought to significantly compromise the study's objectives – testing the protocol and determining variability in Pd-area.

Potential Bias

A SRC reviewer noted that the upstream selection method introduce a bias toward baseflow dominated tributaries by preferring the "wetter" channel to its head. Only 85 surveys of the 128 surveys using the upstream protocol selected tributaries and of those 49 were based on difference in flow category and are thus biased. The basin areas estimated from the 42 biased surveys and those estimated by the 152 non-biased surveys are shown below and are statistically similar at $p = 0.05$. The complete bias analysis is included as **Appendix L**.

Statistic	**Eastside**	**Westside**	**Coastal**
	Biased		
Count	11	26	5
Median	11.5	11.3	3.2
1st Quartile	2.6	4.3	3.1
3rd Quartile	278.2	27.7	4.9
	Unbiased		
Count	32	108	12
Median	38.4	6.9	1.6
1st Quartile	14.0	3.6	0.7
3rd Quartile	67.5	20	4.0

Table 11. Study area descriptions including both hydrologic and watershed variables. In this table all units are in acres and feet. Elsewhere in the text, distances are reported in meters.

Study Area Descriptors					Pd Variables			Watershed variables			
Default Area	Ecoregion	Coop	Sites	Statistic	Pd-area (acres)	Pd-Dist.(ft)	Ch - Pd Dist. (ft)	Av. An. Ppt (in)	Elev. (ft)	Divide Relief (ft)	Divide Gradient
Eastside (300 acres)	Cascades (4)	YAK	13	Median	13	1,150	11	61	4,460	396	104%
				1-Qtile	3	863	0	59	3,966	155	70%
				3-Qtile	43	1,349	40	63	4,532	449	129%
	Eastern Cascades (9)	LVF	2	Median	46	2,691	ND	54	444	215	35%
				1-Qtile	37	2,358		54	413		
				3-Qtile	55	3,025		55	475		
	Northern Rockies (15)	COL	6	Median	229	4,644	ND	20	4,054	373	28%
				1-Qtile	176	3,817		16	2,371	320	18%
				3-Qtile	793	6,156		23	4,441	410	30%
		SPO	6	Median	105	3,226	ND	15	2,328	104	6%
				1-Qtile	47	2,305					
				3-Qtile	302	4,134					
	Northern Cascades (77E)	COL	5	Median	39	1,943	180	24	4,715	516	90%
				1-Qtile	30	1,553		21	4,086	379	79%
				3-Qtile	54	2,014		29	5,952	646	98%
		LVF	12	Median	9	1,109	3	35	3,883	429	41%
				1-Qtile	4	753	1	33	804	85	29%
				3-Qtile	21	1,841	8	57	4,108	500	150%
Westside (52 acres)	Coast Range (1)	DFW	34	Median	5	892	14	90	1,320	322	117%
				1-Qtile	4	654	1	81	1,064	226	104%
				3-Qtile	8	1,142	1	98	1,739	465	144%
		LVF	3	Median	8	889	14	69	1,017	231	84%
				1-Qtile	5	677		69	958	184	83%
				3-Qtile	8	1,066		73	1,233	272	85%
	Puget Lowland (2)	LVF	4	Median	12	1,629	1	30	1,973	392	19%
				1-Qtile	7	1,246		25	1,240	216	
				3-Qtile	70	2,553		37	3,010	531	
		PGS	4	Median	16	689	ND	37			
		SUQ	6	Median	8	846	0	54	325		
				1-Qtile	4	845	0	49	290		
				3-Qtile	25	2,057	0	61	379		
	Cascades (4)	LVF	15	Median	6	981	27	85	1,520	298	80%
				1-Qtile	4	877	10	66	1,317	198	65%
				3-Qtile	16	1,314	52	88	1,957	326	82%
		TCG	61	Median	19	1,347	29	71	2,361	286	86%
				1-Qtile	4	769	14	67	1,759	158	43%
				3-Qtile	44	2,508	29	77	3,040	730	120%
	Northern Cascades (77 West)	SSC	25	Median	5	1,014	0	74	1,631	453	158%
				1-Qtile	3	774	0	71	1,405	299	135%
				3-Qtile	11	1,679	24	77	2,164	972	187%
Coast (13 acres)	Coast Range (1)	HOH	22	Median	3	636	1	125	1,119	241	168%
				1-Qtile	1	387	1	125	723	149	95%
				3-Qtile	5	807	6	125	1,271	331	192%

Study Areas

The watershed characteristics of the 15 study areas in **Figure 1** are summarized here and in **Table 11** to provide a context for the basin descriptions to follow.

Average Annual Precipitation: The long-term (PRISM) average annual precipitation for a study area ranges from 375 mm (15 inches) on the Eastside to 3,125 mm (125 inches) on the Westside (**Figure 8**).

Elevation: The median elevation of study areas range from 100 meters (~300 feet) in the Puget Lowlands (ecoregion 2) to 1,400 meters (~4,700 feet) in the Northern Cascades (ecoregion 77E) and Northern Rockies (ecoregion 15) with the higher median elevations on the Eastside.

Divide Relief: Divide relief is generally between 70 and 200 meters (~210 and ~600 feet) and is greatest (>200 meters) in the Northern Rockies (ecoregion 15)

Divide Gradient: Median divide gradient ranges from a low of 19% in ecoregion 2 (Puget Lowland) to 168% in ecoregion 1 (Coastal Range) with the steepest gradients in the Coastal Ranges and Northern Cascades (<158%).

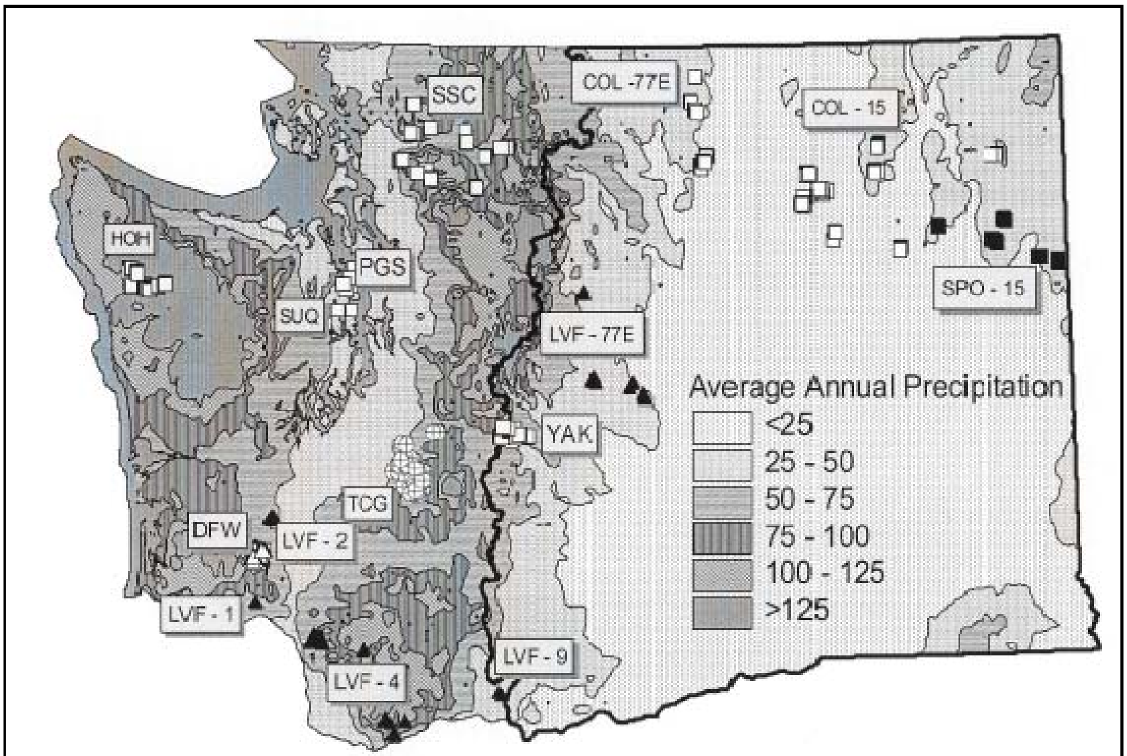


Figure 8: Average Annual Precipitation Classes. The distribution of study areas relative to average annual precipitation classes developed from PRISM data. A heavy north-south line shows the Cascade crest. It divides the state into Eastside and Westside FFR default regions. Note that sites occur in all precipitation classes and that some precipitation classes appear on both sides of the Cascade crest.

Year of Normal Rainfall

Precipitation data from the closest long-term meteorological station to each study area are presented in **Table 12**. Key observations are:

- The 2001 water year was “unusually dry” for all stations;
- The water year shortfall resulted from four consecutive “unusually dry” winter months (Nov-Feb);
- A return to moderately to unusually wet conditions occurred in March or April and continued through August or September;
- On the Eastside the moderately to unusually wet months alternate with moderately to unusually dry months;
- July was moderately dry at most stations.

Detailed interpretation of **Table 12** is deferred to the Discussion section.

Table 12. Year of Normal Precipitation. Precipitation data for the water year 2001 summarized by the meteorological station closest to each study area. The monthly and annual data are compared to the long-term record for the station and assigned to the appropriate quartile of the precipitation distribution.

Precipitation Station	2000			2001									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Coastal													
Forks (HOH)	*9.8*	***6.3***	***10.1***	***13.6***	***3.8***	*9.6*	9.4	6.4	3.6	*1.2*	**7.6**	4.7	***86.1***
Westside													
Bremerton (Suq)	4.7	***4.0***	*6.2*	***4.4***	***2.3***	**4.9**	*2.9*	*2.8*	**3.0**	**1.7**	**3.7**	*0.6*	***41.9***
Doty (DFW)	*3.8*	***3.5***	***2.2***	***3.4***	***2.4***	***3.7****	3.9	2.8	2.7	*0.5*	**1.5**	*0.9*	***31.4***
Skamania (LVF)	7.0	***5.6***	***6.0***	***4.7***	***3.4***	*8.1*	7.1	4.4	**5.6**	*1.1*	2.0	***1.5***	***56.5***
Longmire (TCG)	*7.5*	***6.0***	***4.9***	***5.3***	***4.2***	*6.7*	6.1	4.9	**6.3**	*1.4*	1.4	*1.2*	***56.1***
Sedro Woolley (SSC)	4.3	***2.4***	***3.6***	5.0	***1.8***	4.3	**4.3**	*2.6*	5.0	*1.0*	2.0	*1.6*	***37.9***
Eastside													
Leavenworth (LVF)	*1.2*	***1.5***	*2.3*	***1.6***	***1.5***	2.1	***0.6***	***0.8***	1.2	**0.0**	**0.6**	0.2	***13.6***
Republic (COL)	*0.9*	***0.9***	*1.1*	***0.6***	***0.4***	1.7	***0.6***	***0.7***	1.8	*0.9*	***0.2***	0.9	***10.7***
Stampede Pass (YAK)	*4.0*	***5.8***	***5.6***	***5.6***	***4.0***	7.7	6.2	*4.2*	4.4	*1.4*	1.4	***1.2***	***51.5***
Winthrop (COL)	1.0	*1.2*	*1.2*	***0.5***	***0.7***	1.0	*0.4*	***0.1***	*0.8*	*0.6*	*0.3*	0.5	***8.3***

Category Codes		
	Bold underlined italics = Unusually Dry	< 25th percentile of long term record
	Italics = Moderately Dry	25th to 50th percentile of long term record
	Regular = Moderately Wet	50th to 75th percentile of long term record
	Bold Regular = Unusually Wet	> 75th percentile of long term record

Basin Area Variability

A total of 109 basin areas (Ch, Pd, and Pc) were determined for Eastside sites and 385 (Ch, Pd, and Pc) were obtained for Westside sites. The summary statistics for observed Pd-areas by FFR default region are included in **Table 13** and the distribution of Pd-area by default regions is shown in **Figure 9**. The average observed Pd-areas for the three FFR default regions (Coastal, Westside, and Eastside, respectively) are 8, 22, and 118 acres and the median observed Pd-areas are 2, 6, and 36 acres. The observed values are considerably smaller than the FFR default basin areas of 13, 52, and 300 acres.

Table 13: Basin Areas above Pd. Descriptive statistics of basin areas above Pd (Np/Ns break) by FFR default region.

Statistics	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)
Sample Size	43	152	18
Average (acres)	118	22	8
Median (acres)	36	6	2
Minimum (acres)	0.4	0.1	.3
Maximum (acres)	1,224	260	85
1st Quartile (acres)	9	3	1
3rd Quartile (acres)	68	22	5
Coefficient of Variation	206	191	249

The distribution of Pd-area in the different default regions is similar (**Figure 9**). The distribution peaks around 3 acres with a long tail toward larger basin areas. The differences in the distributions appear to lie in the frequency and size of the larger basins within each default region.

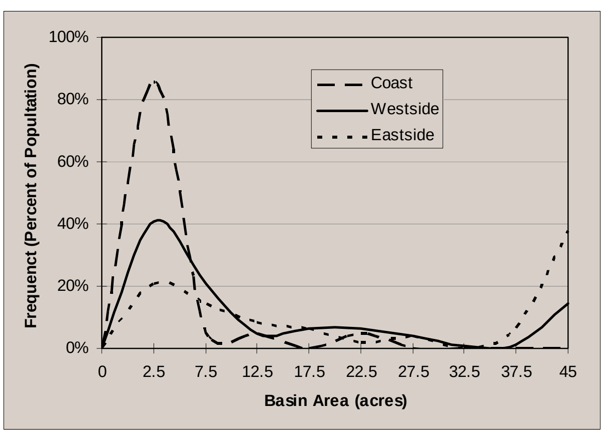
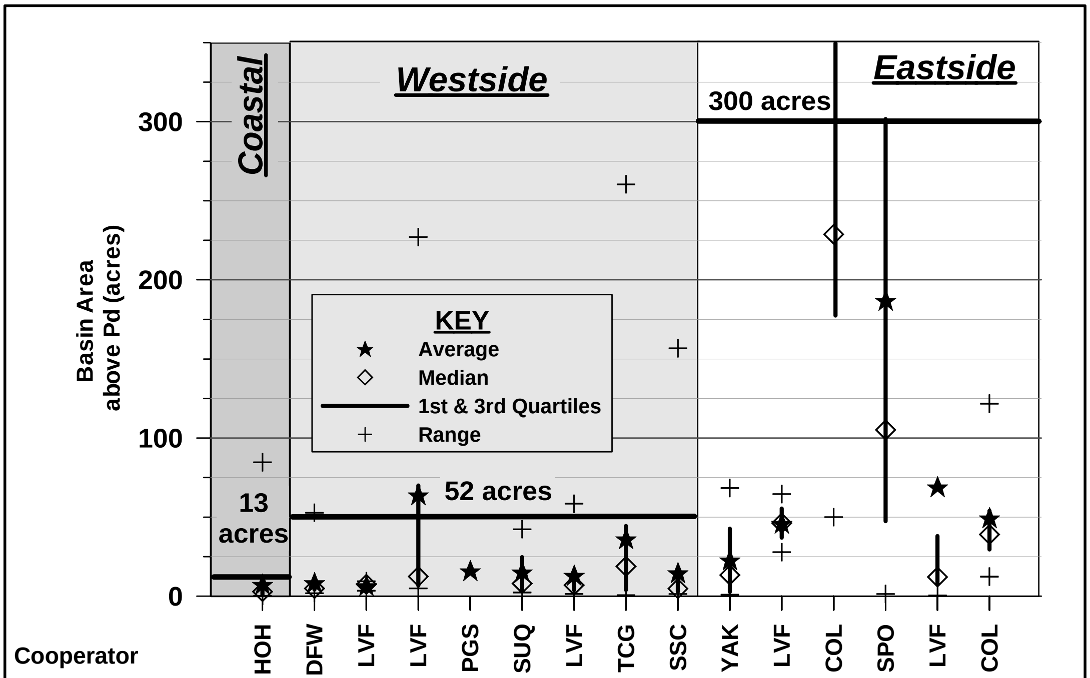


Figure 9. Basin Area Distribution. Distribution of Pd-area by FFR default region. The basin area frequency curve for each default region peaks around 3 acres. The differences in the median basin area between regions likely result from differences in the tails of the distribution - those beyond 10 acres - that differ for each default region.

Pd-areas differ between study areas within the state, between default region, and within some ecoregions (**Table 11, Figures 9** and **10**). In **Figure 10** the average and median of Pd-area are shown as points (star and diamond, respectively), the central 50 percent of the data as defined by the first and third quartiles is a solid line, and crosses bracket the range. The distributions in **Figure 10** indicate that:

- The FFR default basin area is larger than 75% quartile of the observed Pd-areas in 13 of the 15 study areas



Cooperator	HOH	DFW	LVF	LVF	PGS	SUQ	LVF	TCG	SSC	YAK	LVF	COL	SPO	LVF	COL
Number of Sites	22	34	3	4	1	6	15	61	25	13	2	6	6	13	5
Ecoregion	1	1	1	2	2	2	4	4	77W	4	9	15	15	77E	77E
Average Area (acres)	8	9	7	64	16	15	13	36	15	23	46	494	187	69	50
Median Area (acres)	3	5	8	12		8	7	19	5	13	46	229	105	12	39

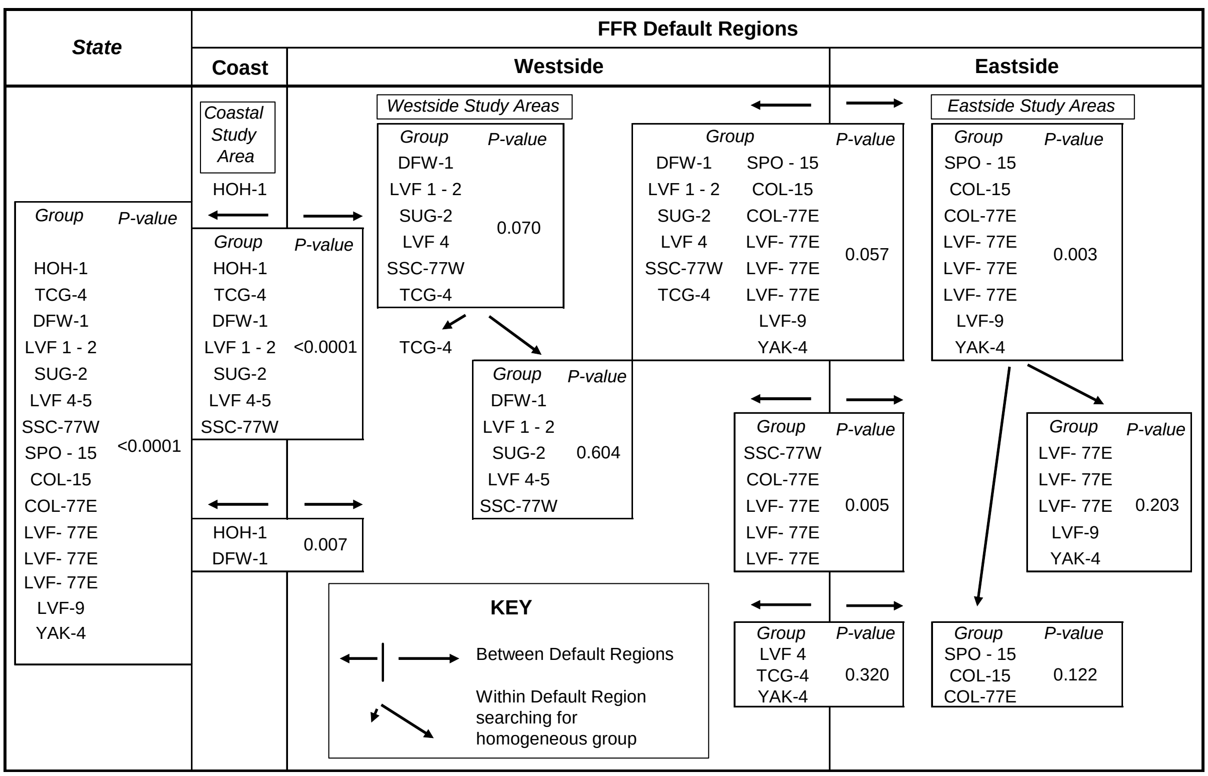
Figure 10: Basin areas above Pd by study area. Study areas are identified by cooperator (Table 3) and ecoregion (Figure 1). The heavy horizontal line in each FFR default region defines the default basin area for that region. The average and median values for each study do not coincide because of the skewed, lognormal distribution of the basin areas. Surveys in COL-15, SPO-15, and TCG did not reach the channel head and the basin areas may be biased toward larger areas in these study areas. The COL-15 distribution is truncated

- Within each FFR default region, the data distribution for each study area as defined by the 1st and 3rd quartiles overlaps that of the others in 13 of the 15 study areas
- The study areas in ecoregions 4 and 77, which straddle the Cascade crest thereby including both Eastside and Westside default regions, may have similar distributions of Pd-area.

These observations were tested by ANOVA. **Table 14** shows the groupings and probability (p) of the null hypothesis – no significance difference --- for each grouping. Significant differences (p <0.0001) exist between study areas when grouped by the state as a whole. When the state grouping is disaggregated into default regions, significant differences remain between the study areas in the Eastside (p= 0.003) and Westside (p = 0.07) groupings. When these default- region groupings are subdivided into two groups based on average log Pd-area, the differences within them become non-significant (0.1 >

p < 0.6). These smaller default-region groupings indicate that on the Westside, the average log Pd-area in TCG-4 is significantly different from the average log Pd-area in the other Westside study areas, and on the Eastside the average log Pd-area in SPO and COL study areas are significantly different than the average log Pd-area in the LVF and Yak study areas. Pd-areas in the SPO, COL, and TCG study area are larger than those in the other study areas in the default region (**Table 11**). As noted elsewhere, the surveys in the SPO, COL, and TCG study areas captured fewer channel heads (**Table 3**), which could lead to misidentification of Pd and larger Pd-areas.

Table 14: Results of ANOVA between study areas grouped by ecoregion and FFR default region. Each box contains a study-area grouping and the probability of significant difference within the group. Study area names are composed of the cooperator (Letters) and the ecoregion number. Groupings crossing a default-region boundary as indicated by the horizontal arrows compare study areas in both default regions to determine differences between them. Groupings within a default region compare study areas within that default region. When significant differences exist in a within-region grouping it is divided into two internally homogeneous groupings as indicated by the diagonal arrows.



Significant differences in log Pd-area occur between some study areas within the same ecoregion. The HOH-1 study area and the DFW-1 study lie on opposite sides of ecoregion 1 (**Figure 1**) and their average log Pd-areas are significantly different (p = 0.007). Within ecoregion differences also exist for ecoregion 77, which is divided into 77-E and 77-W (for east or west of the Cascade crest). The significant difference in average log Pd-area between the HOH-1 and DFW-1 indicates the placement of the HOH-1 study area into the Coastal default region is reasonable

The average log Pd-areas for study areas within some ecoregions are not significantly different. Within ecoregion 4 ($p = 0.320$), in which YAK-4 lies east of the Cascade crest and LVF-4 and TCG-4 lie west of the Cascade crest, the average log Pd-areas are not different at $p = 0.254$. The larger Pd-areas in TCG-4 appear to be more similar to YAK-4 on the Eastside than to the Pd-areas in the other Westside study areas.

Sample Size

The sample size required to estimate the observed median basin areas described in **Table 13** at the 90% confidence interval changes with the precision selected. With a 10% precision, it is estimated as 84 and 99 for the Eastside, and Westside, default regions respectively (the Hoh study area is excluded from Coastal FFR, for the sample size analysis). If the precision is decreased to 15%, the sample sizes become 38, and 45 or about half of the size estimated with 10% precision. Sample size requirements are more fully developed in the Discussion section.

Field Indicators of the Np/Ns Break

The search for a definitive field indicator for the Np/Ns break was unsuccessful, with the exception of the channel head. Changes in flow category accounted for 2,361 segment breaks. However only 117 (5%) of these were actual Pd locations and only 57 (44%) of these had associated features recorded. In **Figure 11** the frequency of associated features at Pd segment breaks are compared with their frequency at other flow-change segment breaks. The most frequently noted features were "springs", "seeps", and "wetlands", which occurred at over 70 percent of the Pd and

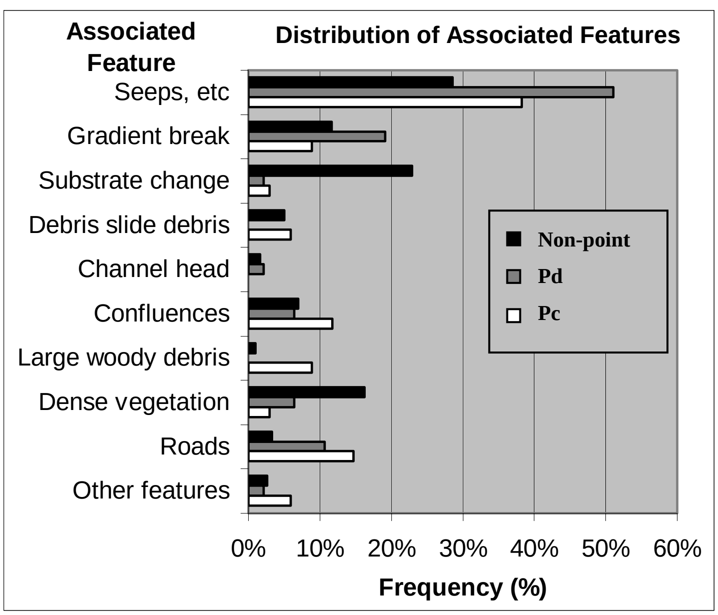


Figure 11: Histogram of associated points at flow-generated segment breaks. The histogram compares the frequency at which associated features occur at segment breaks defined by a change in flow category.

Pp breaks, and are the only FFR criteria for identifying the Np/Ns break. Roads are the only other associated features that are more frequent at Pd and Pp than at other flow-category breaks. Because springs, seeps, and roads are commonly found elsewhere they show little potential to conclusively identify Pd outside the dry season. Likewise, none of the other associated features appear to be definitive field indicators of the Np/Ns break.

Changes in channel variables at Pd were determined by comparing the segment upstream of Pd to the segment downstream. The variables included in this analysis were:
a) Substrate
b) Bankfull width
c) Bankfull depth
d) Segment gradient
The upstream/downstream values of these variables were not significantly different at $\alpha = 0.10$ and therefore are not suitable field predictors of Pd.

Other Indicators of the Np/Ns Break

Because the search for field indicators of Pd did not provide channel-scale predictors, other possible candidates were sought at the reach- and site-scales. These indicators include the channel head (Ch), seasonal reach length (Ch – Pd), and distance from the divide (Pd-distance).

Potential site-scale indicators of the Np/Ns break are the channel head (Ch) and length of the seasonal reach. The channel head lies close to the Pd. As shown in **Table 15**, the average length of the seasonal reach (Ch – Pd) is less than 35 meters (115 feet) and the corresponding median length is less than 17 meters (54 feet). In place of other indicators, placement of the Np/Ns break (Pd) at the channel head would result in a median error of less than 10 meters (30 feet) in the Eastside, 21 meters (63 feet) in the Westside, and 2 meters (6 feet) in the Coastal default region. This error is much less than that associated with the present FFR default basin areas.

Another indicator is the length of the seasonal reach (Ch – Pd). As shown in **Table 15** the average length of the seasonal reach is similar for the Eastside and Westside regions – 21 to 24 meters (67 to 79 feet) with springs/seeps included and around 29 to 35 meters (93 to 112 feet) with them excluded. It is lower in the Coastal region with an average length of 4 meters (13 feet) with springs/seeps and 5 meters (16 feet) without them. The presence of channel head springs/seeps in the sample affects its coefficient of variation (C.V.). When channel head springs and seeps are included the C.V.s are between 136 % and 353% and generally exceed those of default basin areas (182% to 249%). When channel head springs/seeps are excluded, the C.V.s decrease to between 118 % and 210 % and are less than those for default basin areas.

Table 15: Length of seasonal reach (Ch – Pd). Descriptive statistics for the length of the seasonal reach (meters) with reaches beginning at channel head (Ch) springs and seeps included (left) and excluded (right) from the sample

Statistic	Channel Head Springs and Seeps Included			No Channel Head Springs and Seeps		
	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)
Sample Size	23	126	18	16	92	15
Average	24	21	4	35	29	5
Median	6	10	2	10	17	2
Minimum	0	0	0	1	1	1
Maximum	180	225	22	180	225	22
1^{st} Qtile	0	0	1	5	7	1
3^{rd} Qtile	22	27	6	37	37	8
Coefficient of Variation	187	353	136	147	210	118
Channel head springs or seeps	7 (30%)	34 (27%)	3 (17%)	0	0	0

Site-scale candidates for an alternate indicator for Pd were sought through the correlation of observed basin areas with the site-scale topographic parameters in **Figure 4**. In this analysis, the data were pooled at the state level to provide data sets that ranged between 105 and 162 pairs. Log Pd-distance is the only meaningful correlation at r^2 =0.75 **(Table 16**) and its relationship to the observed Pd-area was explored.

Table 16: Basin area correlation with site variables to determine which site variables covary with basin area. Correlations expressed as r^2 between Pd basin area and site variables. All r^2 are significant at $\alpha = 0.1$ but only those correlations with $r^2 > 0.50$ are considered meaningful.

Variable	Log Pd Basin area	Sample Size
Log Ppt	-0.25	162
Db Elevation	0.13	124
Dc Elevation	0.12	150
Pd Elevation	0.08	157
Basin Relief	0.27	120
Divide Relief	0.19	146
Log Dc - Pd	0.77	125
Log Divide Gradient	-0.16	105

The summary of Pd distances by FFR default region (**Table 17)** indicates the average Pd-distances are short being 245 meters (804 feet) in the Coastal region, 431 meters (1,379 feet) in the Westside, and 780 meters (2,558 feet) in the Eastside.

Table 17: Distance from divide to Pd. Descriptive statistics for distance from divide (Dc) to Pd by FFR default regions.

Statistic	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)
Sample Size	38	117	18
Average (m)	780	431	245
Median (m)	538	333	212
Minimum (m)	44	39	39
Maximum (m)	2,933	1,534	1,065
1st Qtile (m)	327	214	132
3rd Qtile (m)	1,038	544	248
Coefficient of Variation	94	74	90

Corresponding median Pd-distances are 538 meters (1,765 feet), 333 meters (1,065 feet) and 212 meters (695 feet) in the Eastside, Westside and Coastal regions, respectively. Their C.V.s are less than 95 %, which makes Pd-distance significantly less variable than observed Pd-area (C.V.> 182%).

Pd-distance is strongly related to observed Pd-area (**Figure 12).** Regressions of Pd-distance upon observed Pd-area are significant (**Appendix** I) for (1) sites within a study area, (2) study areas within a FFR default region, and (3) default regions within the state. Analyses of covariance of the interaction of study areas indicate no significant differences (p>0.2). The state regression in **Figure 12** thus expresses the relationship between observed Pd- area and Pd-distance at all study areas across all ecoregions.

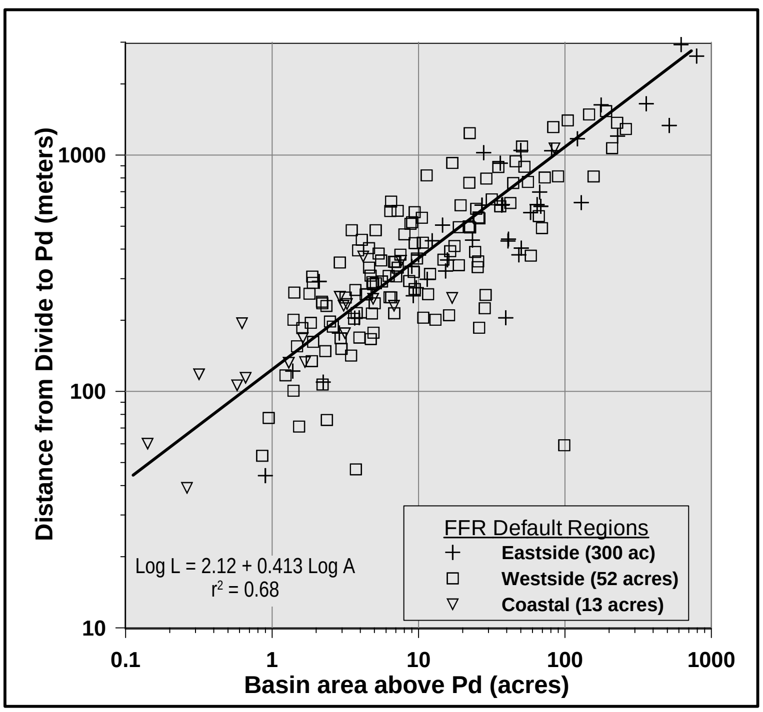


Figure 12: Distance from divide vs. Basin area. Scatter diagram showing the relationship between distance from divide to Pd and basin area above Pd. Regression equation for all data is highly significant.

Alternative Stratification Schemes for FFR Defaults

We tested three alternative hypotheses for establishing

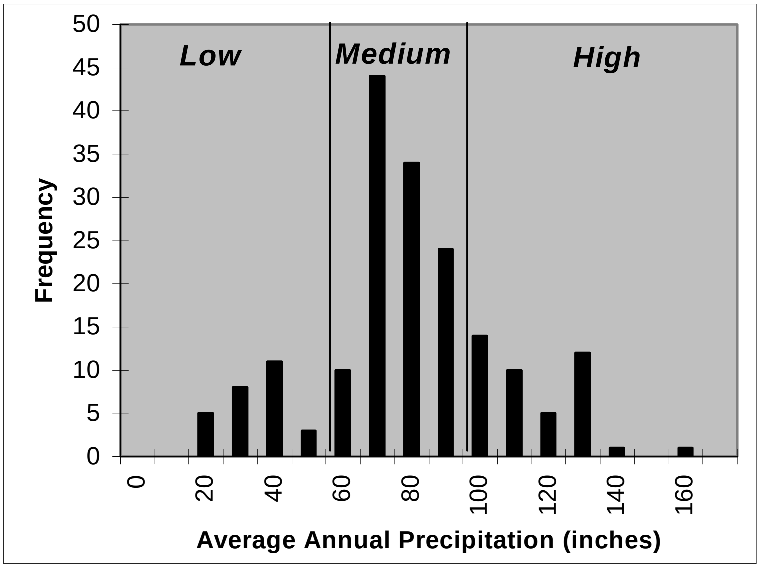


Figure 13: Histogram of Average Annual Precipitation. The frequency of precipitation values occurring at Pd in 218 study sites in the state. The precipitation classes used in the analysis are labeled Low through High.

FFR default regions based on a single physical attribute – average annual precipitation, elevation, and relief. Because Pd-areas were not significantly different when grouped into three classes based on elevation or relief, these two attributes were eliminated as potential criteria. Precipitation classes have significantly different Pd-areas and slightly lower C.V.s.

The distribution of the average annual precipitation in Washington is shown in **Figure 8**, which is based upon PRISM model data. These data were used to determine the precipitation distribution at Pd (**Figure 13)**, which was divided into three classes for a preliminary analysis of basin areas:

- Low (<30 to 60 inches, <750 to1,500 mm)
- Medium (60 to 100 inches, 1,500 – 2,500 mm)
- High (100 to 160 inches, 2,500 to 4,000 mm)

Table 18 presents the median and average observed Pd-areas for the three precipitation classes. With increasing average annual precipitation, the average Pd-areas decrease from 122 acres to 10 acres, and median Pd-areas decrease from 27 acres to 3 acres. ANOVA indicates that the Pd-areas in the different precipitation classes are significantly different. The C.V.s for the three-precipitation classes ranges from 163% to 281% and are similar to the C.V.s for default regions (182% to 249%).

Average annual precipitation may be an appropriate tool for determining default regions because Pd-areas vary inversely with average annual precipitation as shown in **Figure 14**. ANOVA indicates it is highly significant ($\alpha < 0.001$) although the explanatory power is not great with an $r^2 = 0.20$. The large variability around this trend indicates the importance of other contributing factors.

Table 18: Basin area above Pd by precipitation class. Class boundaries selected to divide precipitation range into approximately equal cells. Total number of sites in "Included sites by FFR default region" exceeds number used to develop statistics because not all included sites had basin area data.

Statistic	Average Annual Precipitation Class		
	<30 - 60 In (<7750 - 1,500 mm)	60 - 100 in 1,500 mm - 2,500 mm)	100 - 160 in (>2,500 mm)
Number of Sites	49	127	31
Average	54.6	38.0	3.6
Median	18.9	6.8	1.8
Minimum	0.4	0.7	0.3
Maximum	515.6	793.1	20.6
1st Qtile	6.8	3.5	1.2
3rd Qtile	58.3	22.4	3.5
COV	175.8	281.1	129.6
Sites by Default Region			
Coastal	0	0	21
Westside	16	124	10
Eastside	33	12	1

Table 19. Distance from divide by Precipitation Class. Distance between point Dc on the drainage divide and point Pd.

Statistic	Average Annual Precipitation Class		
	<30 - 60 In (<7750 - 1,500 mm)	60 - 100 in 1,500 mm - 2,500 mm)	100 - 160 in (>2,500 mm)
Number of Sites	41	120	30
Average	737	429	251
Median	581	339	230
Minimum	47	44	39
Maximum	2,933	1,534	1,065
1st Qtile	284	215	132
3rd Qtile	1,043	543	257
COV	86	71	89

Average annual precipitation classes also separate distance from divide to Pd into discrete classes with a low variance (**Table 19**). The precipitation classes indicate that distance from divide to Pd decreases from and average of 737 meters (2,417 feet) in drier areas to 251 meters (823 feet) in wetter areas and the median distances decrease from 581 meters (1,906 feet) in drier areas to 230 meters (754 feet) in wetter areas (the Eastside statistics are biased by the inclusion of sites wherein the channel head was not captured by the survey).

Intra-annual Variability

Figures 15 and **16** depict the changes in flow categories and the location of Pd and Pc in the five sites with multiple surveys during the summer of 2001. Both figures include the storm of August 21 – 22. The relative amount of perennial water between Ch and Pc is shown in **Figure 15**. No consistent pattern of drying is evident except that the August storm appears to have increased the degree of wetness within the channels.

Figure 16 shows the relative change in the distances between the channel head (Ch) and Pd and Pc. Both Pd and Pc appear to migrate downstream during the summer with Pc beginning its migration earlier than Pd. The August 21 – 22 storm does not appear to have affected the migration pattern of Pd and Pc.

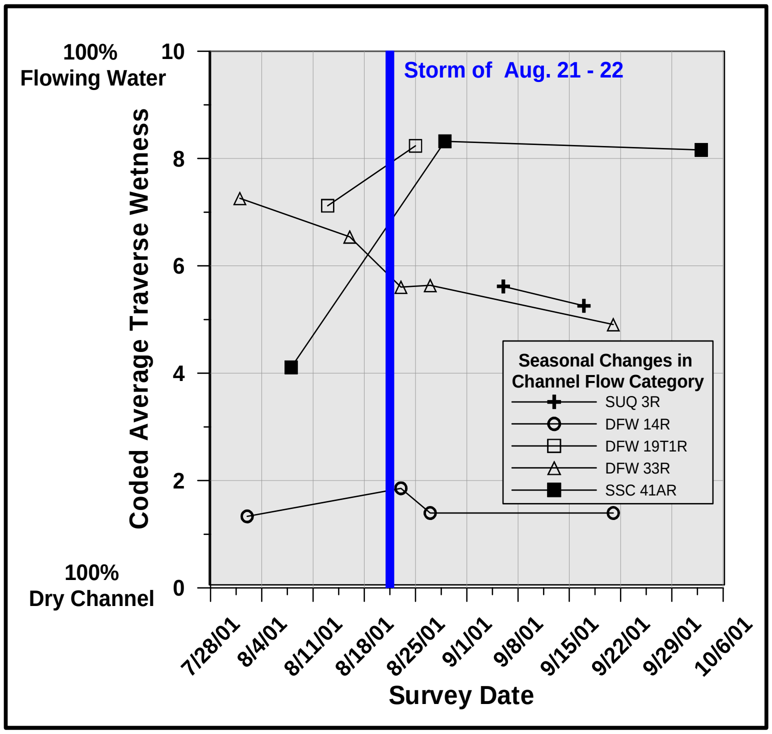


Figure 15: Coded Dryness of repeated surveys downstream from Ch showing intra-annual (seasonal) variation in the amount of perennial water in Type Np channels.

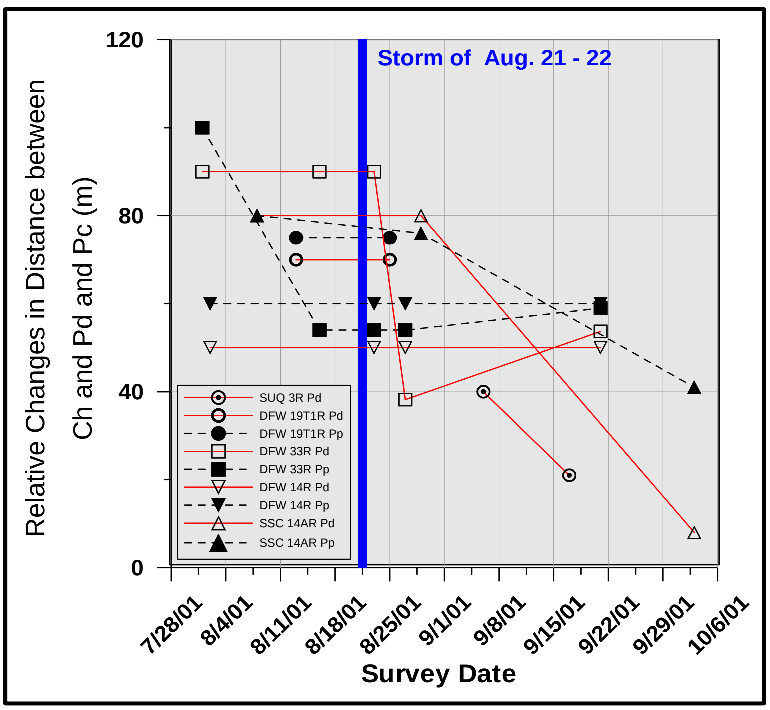


Figure 16: Changes in the position of Pd and Pc relative to Ch. The vertical scale is arbitrary and should be read as change since previous survey. No change produces a horizontal line and upstream migration a downward sloping line.

SECTION 4. DISCUSSION

Protocol

One of the dual purposes of the pilot study was to determine the adequacy and replicability of the pilot protocol. Replicability testing was only partially realized because most cooperators failed to conduct replicate surveys and the independent contractor conduct three replicate surveys. The result is that the replicability of the pilot protocol can not be fully and quantitatively assessed. The available information indicates that the observed field crews behaved differently. The identified problems are not deficiencies of the protocol but of management because segment break requirements are clearly specified in the protocol.

However, if the test of the pilot protocol is “Did it provide the necessary information?” The answer is that the field protocol is generally adequate but requires some modifications. The parameters included in the pilot study proved to be adequate to address the critical concerns of identifying and locating Pd, determining the variability of basin areas, and identifying possible alternative default criteria. Some additions and deletions are recommended to either streamline data collection or to provide the additional data required for new hypotheses recommended for testing. New parameters recommended for inclusion in the protocol are channel head, valley width, debris-flow scour, and debris-flow sediments. Recommended for deletion are bankfull channel width and depth.

The channel head (Point Ch) is an important hydrologic feature as it marks the beginning of channelized stream flow and usually can be identified during most seasons. Inclusion of Ch was not required by the pilot survey because the emphasis was on point Pd. Numerous surveys that did not reach the channel head may have missed isolated wet channels segments upstream of the previously identified Pd and thereby increased the average basin areas and distances from divide (Dc – Pd) and from the channel head (Ch – Pd). Because the channel head appears to vary in shape and degree of definition (Dietrich and Dunne, 1993; Roth and La Barbera, 1997), there should also be a certainty assessment (e.g. “definite”, “certain within a few channel widths”, “gradational over X distance”, “uncertain”).

The importance of valley width is uncertain. It may be an important control on the expression of surface flow (Kasahara and others, 2003; Storey and others, 2003) because it along with sediment depth and permeability controls the quantity of subsurface flow through the alluvial fill within the valley. Zellweger and others (1989) found that subsurface flow through alluvium could amount to about 25 percent of the surface flow and that aggradation of coarse sediment can increase the proportion of subsurface flow. Its inclusion in the study would allow the more complete analysis of the controls on Pd and the observed variability in basin area and distance downstream.

The addition of two channel categories would facilitate the assessment of debris-flow impacts. The additional channel categories are:

- "Debris-flow scoured" valleys containing little to no sediment on the valley floor because of recent debris-flow activity. The lack of sediment inhibits the development of a channel and perennial flow may occur further up stream because of the low storage within the valley. As colluvium and alluvium accumulate on the valley floor, perennial flow may begin farther down stream.
- "Debris-flow sediments" a valley floor containing debris-flow sediments. When the sediments are of sufficient thickness or high permeability surface water may disappear as underflow becomes dominant.

These channel categories will identify debris-flow prone valleys and allow the assessment of their uniqueness and potential impact on the location of the Np/Ns break. It is anticipated that debris-flows may affect a large proportion of the valleys in mountainous areas (Dunne, 1998; Montgomery, 1999; Whiting and Bradley, 1993).

The field parties recommended that bankfull channel width and depth be removed. Bankfull channel width and depth are difficult to measure because in many cases the channel edge is often indistinct in small streams. Because of this problem, the recorded channel widths and depths maybe inaccurate. Bankfull width and depth are more indicative of peakflow discharge rather than lowflows.

Several changes to the protocol would refine the data collected or streamline data collection. Field parties indicated that substrate was difficult to assess for a segment based on flow category. Allowing segment breaks at substrate changes could reduce the substrate identification problem and allow a fuller assessment of the association between substrate and Pd. The field parties also emphasized the large amount of time consumed by recording segment information at segment lengths of 30 meters (98 feet) or less and encouraged the increase in segment length to 100 meters (328 feet). This increase appears reasonable if both changes in flow and substrate categories are criteria for forced segment breaks.

Future surveys should emphasize the site and channel conditions occurring at Pd. Although the field protocol includes lists of possible indicators, the lists may not be sufficiently inclusive and an open-ended description may identify additional indicators.

Often the field coordinates for points do not plot on a recognizable drainage way on the USGS 7.5 minute topographic maps (Meyer and Wallace, 2001). The field party has the best understanding of the relationship of the survey to the topography and topographic map. Therefore they are in the best position to make any changes, such as moving a point to fit map, or plotting the drainage that does not appear on the map.

Year of Normal Rainfall

Different conclusions are possible from the 2001 precipitation data depending on the interval and area analyzed – the 2001 water year for the state or the summer of 2001 for the state default regions. At the state and annual scale, the WY 2001 had an unusually dry winter followed by a variable summer (average to wet on Westside, dry on the Eastside) that produced an unusually dry water year (**Table 12**). Based on the quartile definitions adopted here, 2001 was not "a year of normal rainfall." Rather 2001 was a year of less than normal rainfall that could be expected to produce longer dry reaches within headwater streams and move Pd downstream. Based on this annual assessment, we could anticipate Pd-areas to be larger than normal and the length of the seasonal reach to be longer than normal.

However, the seasonal variations in precipitation may be more important than the annual amount of precipitation. If so, the moderately wet summer months may compensate for the winter drought by providing sporadic recharge to the subsurface reservoir that maintains perennial flow and thereby decreases the Pd-area and shortens the length of seasonal reach.

At the seasonal level, regional differences appear. Summer conditions differed between the Eastside and Westside that could lead to different summer flow regimes. The monthly precipitation on the cooler Westside was typically two to three times larger than that on the hotter Eastside (**Table 12**). It is likely that more of the summer precipitation was lost to evapotranspiration on the Eastside than on the Westside. Consequently, little to no recharge to the soil reservoir would occur on the Eastside and some recharge to the reservoir could occur on the Westside. Based on this reasoning, it is likely that during the summer of 2001 the Eastside had unusually dry flow conditions while the Westside had normal flow conditions.

The "year of normal rainfall" raises two issues that are perhaps more important than the particulars of the 2001 water year. These are:

1. The FFR definition of "normal" is defined as annual, which precludes the use of seasonal precipitation data; seasonal precipitation may have a stronger control on the location of Pd
2. Precipitation is highly variable, so normalcy should be determined regionally.

The analysis presented here indicates that normalcy should be defined on a seasonal basis and for region smaller in area than the state.

Basin Areas

The observed Pd-areas are less than the FFR default basin areas. As shown in **Figure 9**, the FFR default basin areas are larger than the 75th percentile of the basin area distribution in most study areas. When the data are pooled by FFR default area, the average observed Pd-area in each default region (Coast, Westside, and Eastside, respectively) is 8 acres, 22 acres and 118 acres, which is only 61%, 42% and 39 % of the FFR default basin area. Likewise, the median observed Pd-area is 2 acres, 6 acres, and 36 acres, which are only 15%, 13 %, and 11.5% of the default basin areas (**Table 13**).

The observed Pd-areas in this study do not differ from those reported by other studies. Basin area studies conducted by CMER participants prior to 2001 (**Table 2, Appendix B**) report average basin areas ranging from 11 to 138 acres and median basin areas ranging from 10 to 40 acres. These studies used different protocols to collect the data and different definitions for point "Pd" from those in pilot study, so the similarity of their result to those of the pilot study is striking. This similarity indicates that

1. Differences in the definition of the Np/Ns break (point Pd) do not produce large changes in basin areas, and
2. Most available studies indicate that a smaller basin area is required to maintain perennial flow in headwater stream than envisioned by the default basin areas in the FFR.

The results of a study of perennial flow in Puget Lowland streams indicate larger drainage basin areas (Konrad, 2001). The study included 59 basins throughout Puget Lowland (ecoregion 2) that were surveyed in August 1998 and 1999. This study used stream-gaging records and basin areas above the stream gages to calculate the basin area required to maintain perennial flow at Pc. Streams with recorded surface flow during late summer were designated perennial and those without flow were designated ephemeral (seasonal) and a logistics equation used to estimate the probability of perennial flow with different basin areas. This approach indicated that a 50% probability existed for perennial flow where the drainage basin was less than 1.2 km^2 (296 acres).

Basin Area Variability

The observed Pd-areas differed significantly between FFR default regions and between some ecoregions (**Figure 9, Table 14**). The observed geographic variation in Pd-area may have resulted from inconsistency between cooperators in data collection. As shown in **Table 14**, Pd-areas for the different study areas did not differ statistically when specific study areas were removed from the grouping. On the Eastside, the separation of the COL and SPO study areas from YAK and LVF study areas resulted in two groups with no statistical differences in Pd-area. On the Westside, the removal of the TCG study area from the Westside group resulted in a grouping of statistically similar Pd-areas. As noted earlier, many surveys by the SPO, COL, and TGC did not capture the channel head, which means the actual Pd may lie farther upstream of the Pd identified in these surveys. Misidentification of Pd could produce larger Pd-areas. The median Pd-area in TCG is 19 acres compared to 5 to 15 acres for the other Westside study areas and Pd-area in the COL and SPO study areas are 229 and 105 acres compared to 12 to 46 acres for the other Eastside study areas. The conclusion that these differences may result from observer differences is clouded for TCG-4, which is not statistically different from the other study areas in ecoregion 4 (YAK-4 and LVF-4), and these similarities may be pointing to an unique situation in ecoregion 4. These relationships highlight the importance of capturing the channel head in future surveys because of the close relationship between perennial water and the channel head shown in **Table 15**

Part of the variability in Pd-area may result in part from differences in precipitation as shown by the precipitation analysis (**Table 18**). Castro and Jackson (2001) reached a similar conclusion in their analysis of bankfull discharges in the Pacific Northwest. They determined that although ecoregions included the statistically most significant spatial factors controlling bankfull discharges, climate regionalization was also significantly related to bankfull discharge. The authors attributed this duality to the climate-adapted vegetation associations in each ecoregion that controlled runoff conditions.

The watershed variables used in the pilot study do not appear to control perennial flow. As shown in **Table 16**, Pd-area is not related to elevation or relief. The Puget Lowland study (Konrad, 2001) also found that perennial flow was related only to basin area and not to four other physiographic variables or degree of urban development. They compared perennial flow to basin area, valley slope, valley relief, basin shape, and surficial geology. Perennial flow was related only to basin area and the contact between outwash and till. The study did not determine the changes in the extent of perennial flow that may have occurred during the initial clearing of the forests.

Precipitation Classes Defining Alternate Default Regions

Precipitation may be a more appropriate criterion for identifying FFR default regions. The precipitation classes in **Table 18**, which includes data from all FFR default regions, indicate the inherent heterogeneity of FFR geographically-based default regions. For instance, the less than 60-inch precipitation class includes 33 sites from the Eastside and 13 sites from the Westside. The precipitation class boundaries used in this analysis may not be the most appropriate, and if precipitation is used as the basis for default regions, further study to determine the most appropriate boundaries are recommended.

Alternative Indicators

The phase 1 search for alternative field indicators for the Np/Ns break was partially successful. The existence of a unique and consistent change in some channel feature was not found but the consistent proximity of the channel head to the Np/Ns break makes it an attractive alternate. The lack of unique changes in channel geometry at Pd indicates that either a consistent and unique change in channel geometry does not occur at Pd, or the 2001 protocol was not capable of detecting such a change that indeed was present. The 2001 protocol was capable of identifying several alternatives with lower variability than the present default basin areas.

The channel head may the best alternative field indicator for the Np/Ns break. It has three advantages: (1) It can be identified in the field during most seasons, (2) It does not migrate seasonally, (3) It lies close to the field-identified Pd (**Table 15**), and (4) Its use requires no measurements. A potential disadvantage is that the channel head probably can not be located on maps or aerial photographs without field data. Theoretical and empirical relationships exist for predicting the location of channel heads at the landscape scale (Montgomery and Dietrich, 1989), but the application of these relationships to predict channel head locations in Washington state have been unsuccessful (Jaeger, 2004).

The length of the seasonal reach also can be used in the field to identify the Np/Ns break. Once the channel head is identified, the location of the Np/Ns break in the channel can be determined using its median length (**Table 15**). Seasonal reach length can be used to reduce the discrepancy in distance between Pd and Ch at the expense of measuring a specified distance and placing a monument to mark the regulatory Np/Ns break.

Pd-distance is the third alternative indicator. As shown in **Figure 11**, it is strongly related to basin area (Montgomery and Dietrich, 1992) and as shown in **Table 17**, it has a much lower coefficient of variation (74% to 94%) than default basin areas (182% to 249%). Pd-distance has the advantage of being readily measured on a map and could be the basis for computer-generated default maps within the GIS environment. Pd-distance has two disadvantages; (1) it may be difficult to measure in the field and (2) it may change seasonally as Pd migrates up and down stream.

Sample Size and Design

The skewed distributions encountered in the pilot study skews the confidence interval about the average in the arithmetic data. The confidence intervals are symmetrical in the log-transformed data used to estimate the required sample size, but when back transformed, the confidence interval becomes skewed with a long tail toward larger values (**Appendix H, Figure 1**).

The sample design for the phase 2 statewide study should include:

1. Sample size,
2. Sample distribution, and
3. Stratification.

In order to assure a representative estimate of Pd across the selected strata (e.g. FFR default region or precipitation class), the sites should be selected with equal probability from the FFR lands within each stratum. Moreover, the estimated sample sizes should be considered minimum values so that statistical power will be adequate if actual variance was underestimated.

The estimated sample size depends on the stratification criterion. In **Table 20** sample sizes are listed for two stratification criteria – FFR default regions and precipitation classes -- and for two possible default criteria – basin area above Pd and Distance from divide to Pd. The estimated sample sizes are similar for both FFR default regions and precipitation classes because coefficients of variation for basin areas and for distance from divide do not change significantly. The large difference in sample sizes between potential default criteria -- basin areas and distance from divide -- results from the low CV and large median for the observed distance from divide.

Table 20: Estimated sample sizes. Sample size required to estimate the observed average basin area with a 10 percent confidence interval of different precisions. Average and CV (coefficient of variation) are estimated from the lognormal transformation of the observed data. Precision is the size of the 90% confidence interval as a percentage of the average. Dashes in the precision columns indicate estimated sample sizes less than one.

Default	Stratum			Sample size for a Precision of				
Variable	Cell	Average*	CV*	5%	10%	15%	20%	25%
Basin Areas	*FFR Default Region*							
	Eastside	27	56	329	84	38	22	15
	Westside	6	70	532	134	61	35	23
	Precipitation Class							
	<60”	29	54	329	84	38	22	15
	60” – 100”	9	59	391	99	45	26	18
	100 - 150”	3	137	1,974	532	238	134	87
Distance from Divide to Pd	*FFR Default Region*							
	Eastside	540	14	26	8	--	--	--
	Westside	431	12	26	8	--	--	--
						--	--	--
	Precipitation Class							
	<60”	525	14	26	8	--	--	--
	60” – 100”	341	12	13	9	--	--	--
	100 – 150”	201	13	26	8	--	--	--

Intra-Annual Variations

The limited data presented in **Figures 14** and **15** indicate that each surveyed stream behaved differently in response to seasonal precipitation trends. The large summer storm in August appears to have increased seepage to the channel and thereby increased its ‘wetness” but the storm did not appear to affect the migration pattern of either Pd or Pc. The lack of a consistent pattern may indicate that local conditions are more important that meteorological conditions in controlling the migration of Pd and Pc.

Replicate surveys using a larger sample were conducted in 2002 in the Stillman Basin by DFW. These surveys indicated that both Pd and Pc moved downstream during the August and September of 2002. Pd was more stable, with most points moving less than 10 meters. (Mark Hunter, pers. comm.)

SECTION 5. POTENTIAL STUDIES

In addition to the proposed statewide Np demarcation study outlined in the previous sections, the pilot study raised several related technical questions that could be addressed by either future studies or the proposed statewide study. These questions with an explanation follow.

1. ***Does the first appearance of perennial water in the channel (point Pd) change position relative to the channel head (point Ch) during the summer dry season?***

This question asks if low flow observations collected during one part of the summer dry season is representative of low flow conditions during other parts of the summer dry season. The limited intra-annual variation data collected in this study were not analyzed. Other studies (Mark Hunter and others, 2003) indicate no consistent pattern in the behavior of Pd during the summer. At some sites, the position of Pd was stable throughout the summer dry season, whereas, at other sites, downstream migration of Pd began at different times in August.

The issue of seasonal instability would be addressed by repeated surveys of representative streams beginning with wet conditions during the spring runoff and continuing through the entire summer dry season until wetter conditions return following the winter rains.

2. ***Does categorizing default criteria by annual precipitation classes predict point Pd with less variability than do the existing 13, 52, and 300-acre default area?***

Areas with similar amounts of annual precipitation occur both east and west of the Cascade crest. The analyses in the pilot study indicated that precipitation contributes to the observed variability in basin areas but the observed variability using precipitation classes was almost as large as that using FFR default regions. A study is recommended to determine the source and validity of this variability. A study with a sampling design that controlled for precipitation classes has would have two advantages:

1. It could reduce the observed variability, and
2. It would be based on a single physical attribute, one that has been shown to be a regional control of variability in basin areas and distances from divide.

The precipitation issue is complicated by our incomplete understanding of its control on perennial flow (i.e. is the annual or seasonal precipitation the primary control on Pd?). FFR refers to a "year of normal rainfall" but alternative measures of precipitation (e.g. summer averages, difference between spring & summer, etc) may offer more effective predictors as these measures may be more hydrologically significant to perennial expression.

3. *Is the distance between the channel head (point Ch) or divide and the first downstream appearance of perennial water (Pd) a better predictor of this point than default basin area?*

The FFR requires the identification of simple, non-technical field indicator of the Np/Ns break, here identified as Pd. In most areas during snow-free conditions, the channel head can be identified by trained technicians and a default distance measured downstream from it. Moreover, the divide can be recognized on most topographic maps and the distance from the divide to channel marked off. The consistency of these distances can be evaluated by determining the location of both the channel head and Pd during future surveys.

Several cooperators noted that low relief valleys were sometimes incorrectly mapped or did not appear on the topographic map. The inaccuracy of the topographic base maps may limit the use of the divide as a default criterion (if so, the same limitation exists for default basin areas).

4. *Do headwater streams susceptible to debris flows have different physical characteristics that affect the location of Pd and Pc?*

The pilot survey did not request information on debris-flow activity except to note where debris-flow sediments caused a change in flow category. At least one cooperator (HOH) noted that channels were poorly defined in debris-flow scoured valleys because of the lack of sediment (Dunne, 1998). The location and behavior of Pd and Pc should be different in these valleys (Gomi, 2002).

Several classification of headwater streams that appear in the literature (Montgomery, 1999; Whiting and Bradley, 1993), emphasize the distinction between debris-flow and fluvial dominated valleys. Future studies should include debris-flow prone valleys to determine if they constitute a unique subset.

5. *What is the function of piped channels in the Np stream network?*

This question is important because piped channels are not presently being considered as "typed waters". In 2001, piped channels were surveyed as part of the Np stream network with Ch, Pd and occasionally Pc being located within them. The literature on piped channels and macropores is growing. Piped channels are extremely important conduits of storm flow with the shallow pipes on hillslopes intercepting soil throughflow and conducting it a quickflow to the channel (Jones, 1997; Pearce and others, 1986; Ward, 1984). The subsurface erosion associated with pipe enlargement is main mechanism leading to gully formation [channel head extension] in an area where 70 percent of the stormflow is through piped channels (Swanson and others (1989). Ziemer (1992) noted that the larger pipes in the Caspar Creek Watershed in California maintained summer low flows in drainage basins around one hectare in size. Ground and soil levels in bedrock hollows may be controlled by the depth of macropores and piped channels (Montgomery and Dietrich, 1995) and thus serve an important slope stability function. Piped channels respond quickly to forest harvest, but the biological functions of piped channels have not been assessed.

Future studies could focus on the identification and functions of piped channels to assess their importance to FFR rules and their inclusion in the channel system during the assessment of the Np/Ns break

SECTION 6. SUMMARY

The pilot study confirmed that the pilot protocol was adequate to consistently collect channel data that could be used to identify the Np/Ns break (Pd). The protocol would be improved by requiring the continuous survey of the channel to the channel head.

The pilot study provides some useful insights on the character of headwater streams and default basin areas:

1. ***Perennial water is commonly located near the channel head***. The proximity of the channel head and Pd indicates that: 1) the channel head is a good indicator of the beginning of perennial flow (the Np/Ns break), and 2) the length of seasonal channel is very small relative to the length of perennial channels. This proximity produces a small basin area for Pd and requires the protocol to include the channel head in the survey.

2. ***Channel attributes do not change at Pd***. Changes in channel attributes, such as substrate or width, do not occur at the change from seasonal to perennial water (Pd) in any greater frequency than at other flow break within the stream. It is unlikely that physical attributes can be used to identify the Np/Ns break.

3. ***Observed basin areas for Pd are smaller than FFR default basin areas***: The results indicate that average observed basin areas are around 50% of the default basin areas and the median observed basin areas are less than 15% of the default basin areas. These results are similar to those from earlier studies in Washington.

4. ***The basin areas above Pd vary spatially across the state***. This variation is indicated by the differences between basin areas in different FFR default regions. The preliminary analysis of this spatial variability indicates that precipitation is a stronger control on Pd location than default region.

5. ***Distance from divide to Pd is less variable than basin area***. Although distance from divide to Pd is a function of the basin area above Pd, it is less variable as measured by the coefficient of variation. Its lower variability and greater ease of delineation than basin area makes it an attractive alternative indicator and potential default criterion.

6. ***Sample sizes required depend on the attribute of Pd that is being characterized -- basin area or distance from divide***. Sample sizes are the same for FFR default regions and precipitation classes but differ significantly between variable being measured. Sample sizes required to estimate distance from divide are only 10% of those for basin area.

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REFERENCES CITED

Asano, Y., T. Uchida, and N. Ohte, 2002. Residence times and flow paths of water in steep unchanneled catchments, Tanakami, Japan. Journal of Hydrology, V. 261, p. 173-192.

Castro, J. M., and P. L. Jackson ,2001, Bankfull discharge recurrence intervals and regional hydraulic geometry relationships: patterns in the pacific Northwest, USA. Journal of the American Water Resources Association, V. 37, p. 1249 – 1262.

Clemente, J. C., L. Aquilina, O. Bour, K. Plaine, T. P. Burt, G. Pinay, 2003, Hydrological flowpaths and nitrate removal rates within a riprarian floodplain along a fourth-order stream in Brittany (France), Hydrological Processes, V. 17, p. 1177 – 1195.

Dietrich, W. E. and T. Dunne, 1993, The channel head, in Beven, K. and M. J. Kirby (eds), Channel Network Hydrology, Chichester, U.K., John Wiley & Sons, p. 175 – 219.

Dunne, T., 1980, Formation and controls of channel networks, Progress in Physical Geography, V. 4, p. 211-239.

------------1998, Critical data requirements for prediction of erosion and sedimentation in mountain drainage basins, Journal of the American Water Resources Association, V. 34, p. 795 - 808.

Evans, M., N. Hastings and B. Peacock, 1993. Statistical Distributions, second edition. John Wiley and Sons, New York.

Freer, J., J. McDonnell, K.J. Beven, D. Brammer, D. Burns, R.P. Hooper, and C. Kendal. 1997. Topographic controls on subsurface storm flow at the hillslope scale for two hydrologically distinct small catchments, Hydrological Processes, V. 11, p. 1347-1352.

Gomi, T, R. C. Sidle, and J. S. Richardson, 2002, Understanding processes and downstream linkages of headwater systems, BioScience, V. 52, p. 905 - 916

Haan, C. T., 1977. Statistical Methods in Hydrology. Iowa State University Press, Ames, Iowa.

Hunter, M. A., T. Quinn, and M. P. Hayes, 2003, Dry-season surface water patterns in forested headwater channels of southwest Washington, Unpublished manuscript, Olympia, Washington, Habitat Program, Washington Department of Fish and Wildlife, 21 pages

Jaeger, K. 2004. Channel-Initiation and Surface Water Expression in Headwater Streams of Different Lithology, Unpublish M.S. Thesis, University of Washington, Seattle, WA. 66 pp.

Jones, J. A. A., 1997. Pipeflow contributing areas and runoff response, Hydrological Processes, V. 11, p. 35 – 41.

Kasahara, T. and S.M. Wondzell, 2003, Geomorphic controls on hyporheic exchange flow in mountain streams, Water Resources Research, V. 39

May, C.L. and R.E. Gresswell. 2003. Processes and rates of sediment and wood accumulation in headwater streams of the Oregon Coast Range, USA. Earth Surface Processes and Landforms, V 28: p. 409 - 424.

Meyer, J.L., J.B. Wallace, 2001, Lost linkages and lotic ecology; Rediscovering small streams. p 295 – 317 *in* Press, M.C., N.J. Huntly, S. Levins, eds. Ecology: Achievement and Challenge. Oxford (United Kingdom): Blackwell Scientific.

Montgomery, D.R. and W.E. Dietrich, 1989, Source areas, drainage density, and channel initiation, Water Resources Research, 25, 1907-1918.

Montgomery, D. R., 1999, Process domains and the river continuum. Journal of the American Water Resources Association, V. 35, p. 397 – 410.

Montgomery, D. R., and W. E. Dietrich, 1995, Hydrologic processes in a low-gradient source area, Water Resources Research, V. 31, p. 1 – 10.

--------------., W.E. Dietrich, and J.T. Heffner, 2002, Piezometric response in shallow bedrock at CB1: Implications for runoff generation and landsliding, Water Resources Research, V. 38, p. 1274-1292.

Omernik, J. M., 1987, Ecoregions of the conterminous United States (Map Supplement), Annals of the Association of American Geographers, V. 77, p. 118 – 125, scale 1:7,500,000.

------------------ 1995, Ecoregions – a framework for environmental management, in Davis, W. S. and T. P. Simon, eds., Biological Assessment and criteria – tools for water resources planning and decision making: Boca Raton, Florida, Lewis Publishers, p. 49 – 62.

Oxtobee, J.P.A. and K. Novakowski, 2002, A field investigation of groundwater/surface water interaction in a fractured bedrock environment, Journal of Hydrology, V. 269, p. 169-193.

Pearce, A. j., M. K. Steward, and M. G. Sklash, 1986, Storm runoff generation in humid headwater catchments. 1. Where does the water come from?, Water Resources Research, V. 22, p. 1263 – 1272.

Roth, G. and P. La Barbera, 1997, Morphological characterization of channel initiation. In Gurnell, A. M. and S. M. White (eds), Hydrology; II, Hydrological and Geomorphological Dynamics of Sediment Systems. Physics and Chemistry of the Earth, V. 22, p. 329 – 332.

Smakhtin, V.U., 2001, Low flow hydrology: A review, Journal of Hydrology. V. 240, p. 147-186.

Storey, R.G., K.W.F. Howard, D.D. Williams, 2003, Factors controlling riffle-scale hyporheic exchange flows and their seasonal changes in a gaining stream: A three-dimensional groundwater flow model, Water Resources Research, V. 39, p. 1034-1051.

Swanson, M. L., G. M. Kondalf, and P. J. Boison, 1989, An example of rapid gully initiation and extension by subsurface erosion: coastal San Mateo County, California; Geomorphology, V. 2, p. 393 – 403.

Whiting, P. J. and J. B. Bradley, 1993, A process-based classification system for headwater basins. Earth Surface Processes and Landforms, V. 18, p. 603 – 612.

Winter, T.C., 1999, Relation of streams, lakes, and wetlands to groundwater flow systems. Hydrogeology Journal, V.7, p. 28 – 45.

Zellweger, G. W., R. J. Avanzino, and K. E. Bencala. 1989, Comparison of tracer-dilution and current-meter discharge measurements in a small gravel-bed stream, Little Lost Man Creek, California. U. S. Geological Survey Water Resources Investigation Report 89-4150. U. S. Government Printing Office, Washington, D. C.